THE HYDROGEOLOGICAL SIGNIFICANCE OF THE OAK RIDGES MORAINE

Prepared by
Intera Kenting
1990

GREATER TORONTO AREA GREENLANDS STRATEGY

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REPORT ON THE HYDROGEOLOGICAL SIGNIFICANCE OF THE OAK RIDGES MORAINE

A Background Paper
Prepared for
The Greater Toronto Area Greenlands Strategy
by
Intera Kenting
1990

RECYCLED PAPER

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Dear Friend:

I am pleased to provide you with a copy of the report entitled; The Hydrogeological Significance of the Oak Ridges Moraine.

This report represents the opinions and conclusions of the authors and was prepared as background information for the Greater Toronto Area Greenlands Strategy. Nevertheless, I am pleased to note that the document provides an interesting overview on the subject matter.

Sincerely yours,

Ron Kanter

Ron Kanter, M.P.P.
St. Andrew - St. Patrick

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I INTRODUCTION

1.1 BACKGROUND

In October 1989, St. Andrews-St. Patrick MPP Ron Kanter was appointed by Premier Peterson to develop options for a Greater Toronto Greenlands Strategy in an effort to protect the natural landscape within the Regional Municipalities of Halton, Peel, York and Durham and Metropolitan Toronto, also known as the Greater Toronto Area (GTA).

The Greenlands Strategy will be developed from the results of a number of studies, one of which, is an assessment of the significance of the Oak Ridges Moraine. This report deals specifically with the hydrological significance of the Oak Ridges Moraine Area as outlined in the Terms of Reference (Appendix A) and involves the following key elements:

(1) Review existing information/data on the physiography, soils, geology and natural functions (e.g. recharge/discharge) of the moraine area. Review other information/data pertinent to the study, as deemed appropriate.

(2) In general, assess the significance of the Oak Ridges Moraine as a natural feature in relation to its hydrologic function. Provide a description, maps, etc. outlining the movement of groundwater within and out of the moraine area.

(3) Identify those watercourses within the GTA, flowing north and south, that are considered to originate within the moraine area.

(4) Specifically, assess the significance of the moraine area as a headwater/source area and recharge/discharge area. If possible, quantify (approximate percentage) of base flow per watercourse originating in the moraine area.

(5) To the extent possible, identify the implications of uncontrolled land use changes within the moraine area from a natural processes perspective. Assuming that more urban land use changes will occur in the moraine area, identify types of land uses and other development controls that should be considered to allow the moraine to continue its natural function of water supply and related water quality.

(6) To the extent known, identify specific areas of significant recharge/discharge that should be centred out for special development controls.

(7) Assess the implications of aggregate extraction on groundwater and the ability of the moraine area to perform its natural functions as a source area.

(8) Document all pertinent data in report form.

(9) In carrying out the study, liaise with provincial ministries, conservation authorities, municipal officials, other agencies and groups, academics and individuals, as appropriate.

1.2 DEFINITION OF THE STUDY AREA

The Oak Ridges Moraine forms one of the most prominent surficial features in Southern Ontario extending for more than 160 km from Cramahe Township east of the GTA, to King Township in the west, and forms the height of land between the Lake Simcoe basin to the north and the Lake Ontario Basin to the south.

The extent of the western boundary of the Oak Ridges Moraine has been subject to redefinition over the years (White 1975). Chapman and Putnam (1984) defined the moraine on the basis of physiography or land forms and identified its characteristic hummocky topography as extending from the Trent River to as far west as the Niagara Escarpment. White (1975) proposed to redefine the western boundary of the Oak Ridges Moraine on the basis of surficial

geology to include only the high level sands in King Township between Pottageville and Eversley. Duckworth (1979) defined the moraine using the 274 m (900 ft) contour elevation and his western boundary conforms with that proposed by White (1975).

The hydrology of the Oak Ridges Moraine includes groundwater flow systems and surface water bodies which extend beyond the strict geologic definition of the moraine. Therefore, for the purposes of this report, the study area is referred to as the Oak Ridges Moraine Area, and has been expanded to include significant hydrologic features that flank the moraine. The Oak Ridges Moraine Area is defined in this report as the area which includes; the Oak Ridges Moraine as defined by White (1975), the portion of land south of the Moraine defined by the 244 m (800 ft) topographic contour which is physiographically part of the south slope defined by Chapman and Putnam (1984), the Palgrave Moraine extending from Pottageville to the Escarpment as mapped by White (1975) and the northern extent of "ice contact stratified drift" on the north slope of the moraine.

The south slope is the physiographic region defined by Chapman and Putnam (1984) which lies south of the moraine between the moraine and the 400 to 600 ft a.m.s.l. (above mean sea level) topographic contour. Ice contact stratified drift is the term given to materials deposited in contact with melting glacial ice.

The Oak Ridges Moraine Area and the Oak Ridges Moraine are occasionally referred to in this report as the moraine area and moraine respectively. The Oak Ridges Moraine Area lies within portions of Peel, York and Durham Regions, and the boundary of the study area is shown on Plates 1-5 which accompany this report.

II PHYSICAL FEATURES OF THE STUDY AREA

2.1 PHYSIOGRAPHY AND CLIMATE

Within the Greater Toronto Area, the moraine area extends for approximately 90 km and varies in width from about 4 km at its narrowest point just south of Lake Scugog to about 24 km at its widest point in the Town of Whitchurch Stouffville. It contains the highest elevations between the Lake Simcoe and Lake Ontario basins. Maximum elevations range from 390 m a.m.s.l. (above mean sea level) in the eastern part of Durham Region, to 405 m a.m.s.l. in Uxbridge Township, and to 350 m a.m.s.l. in King Township to the west.

The ground surface within the Oak Ridges Moraine Area has a hummocky or hilly appearance and contains numerous undrained ponds. This landform, otherwise known as knob and kettle topography is typical of morainal areas.

The south slope area which occupies the land south of the Oak Ridges Moraine between the 244 and 274 m elevations consists of gently rolling hills incised by stream valleys.

The climate of the Oak Ridges Moraine Area is temperate owing to the presence of the Great Lakes which serve to minimize temperature extremes. The moraine area divides two climatic regions; the Simcoe and Kawartha Lakes climatic region to the north and the South Slope climatic region to the south (Kaye 1986).

Historical climate information is available from weather stations in and around the moraine area, and includes stations at Richmond Hill, Bolton, Stouffville and Cold Creek Conservation Area. As well, historical data exists for the station at Oak Ridges which is no longer operated.

Thirty year mean daily temperatures for the Oak Ridges station (1951 - 1980) range from -7.9^{o}C in January to 20.4^{o}C in July (Environment Canada). The mean, long term, annual

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precipitation measured in the area ranges from 776 mm (30.57 in.) to 842 mm (33.13 in.). The thirty year average for the period 1941-1970 at the Oak Ridges station is 819 mm (32.23 in.) (Sibul et al 1977). Roulet (1989a) reports a one year total precipitation of 886 mm (34.88 in.) from a weather station in the headwaters of the Duffins Creek. Thirty year temperature and rainfall averages indicate that, compared to Toronto Scarborough station, Oak Ridges station has slightly higher rainfall (827.4mm compared to 807.3mm) and mean daily summer temperatures and slightly lower mean daily winter temperatures. The mean daily temperatures for Oak Ridges is 6.7°C compared to 7.8°C for Toronto Scarborough (Environment Canada).

A summary of precipitation data is given in Table 2.1.

2.2 GEOLOGY

2.2.1 Bedrock Geology

The Oak Ridges Moraine Area is underlain by sedimentary rocks of Middle and Upper Ordovician Age, which exhibit a regional dip of approximately 10 - 15 m/km to the southwest. Rock types are described by Liberty (1969) and Hewitt (1972) and their distribution is illustrated in Figure 2.1. The oldest rocks underlie the east end of the moraine area in Durham Region and consist of Middle Ordovician grey lithographic limestone of the Lindsay Formation. Rock types became increasingly younger toward the western end of the study area and consist of Upper Ordovician shales of the Whitby Formation, grey limestones with interbedded shales of the Georgian Bay Formation and red shale of the Queenston Formation.

The bedrock formations form a ridge beneath the Oak Ridges Moraine, with an elevation of approximately 152 m (500 ft) a.m.s.l. at the east end of the study area (Funk 1977) a maximum of 201 m (660 ft) a.m.s.l. in the Rouge River Duffins Creek drainage basins (Sibul et al 1977), and a maximum elevation of 293 m (960 ft) a.m.s.l. at the west end of the Oak Ridges Moraine (White 1975).

TABLE 2.1

Precipitation in the Oak Ridges Moraine Area

STATION	MEAN ANNUAL RAINFALL mm (in.)	DURATION	REFERENCE
1. Av. of nine stations - Durham County	842 (33.13)	1967-1973	Funk (1977)
2. Oak Ridges	819 (32.23)	1941-1970	Sibul et al. (1977)
3. Richmond Hill	776 (30.57)	1941-1970	Sibul et al. (1977)
4. Duffins Creek headwater	886 (34.88)	1987-1988	Roulet (1989a)

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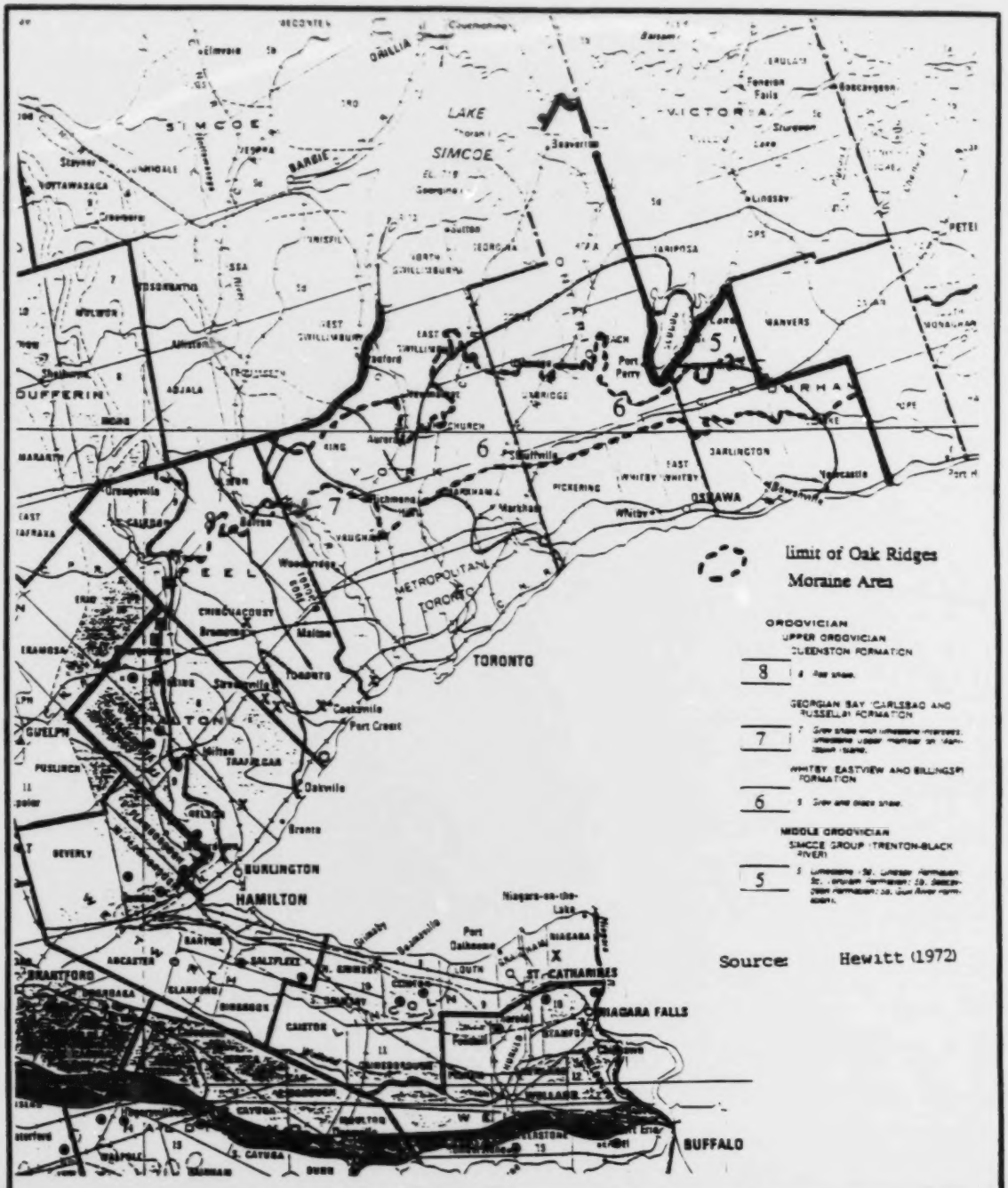

Source: Hewitt (1972)

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Bedrock Geology in the Oak Ridges Moraine Area

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Figure 2.1

The top of bedrock has been mapped using stratigraphic logs from deep water wells and oil and gas exploration holes and indicates that the bedrock is cut by drainage channels which predate the last glacial advance. Bedrock channels have been mapped in the area by Haefeli (1970), White (1975), and Sibul et al (1977).

A major bedrock depression and paleochannel system known as the Laurentian River Channel which provided drainage from Georgian Bay to Lake Ontario prior to the development of the Great Lakes (White and Karrow 1971) has been mapped beneath the west end of the study area (Eyles et al 1986). This system of bedrock depressions facilitated drainage during the early retreat of the last episode of glaciation. Deposition of deltaic sands and silts on the flanks of these depressions had a significant impact on the distribution of deep aquifers in the vicinity of Oak Ridges, Aurora and Newmarket. Figure 2.2 delineates the bedrock channel in the study area between the Niagara Escarpment to the west and Lake Simcoe to the east.

2.2.2 Surficial Geology

2.2.2.1 Previous Work

The last episode of glaciation in Ontario is referred to as the Wisconsinan and was responsible for depositing present soil materials and shaping the landforms that are visible today. Mapping of the surficial geology is well documented within and beyond the study area.

A good general overview of the physiography in the context of other surface features in southern Ontario is provided by Chapman and Putnam (1984). The northern portion of the study area is described regionally by Deane (1950) of the Geological Survey of Canada who described the surficial geology of the Lake Simcoe District. Gravenor (1957) included the eastern portion of Durham Region in his report on the Lindsay-Peterborough area. The Ontario Division of Mines has completed mapping of the western portion of the study area including the Bolton area

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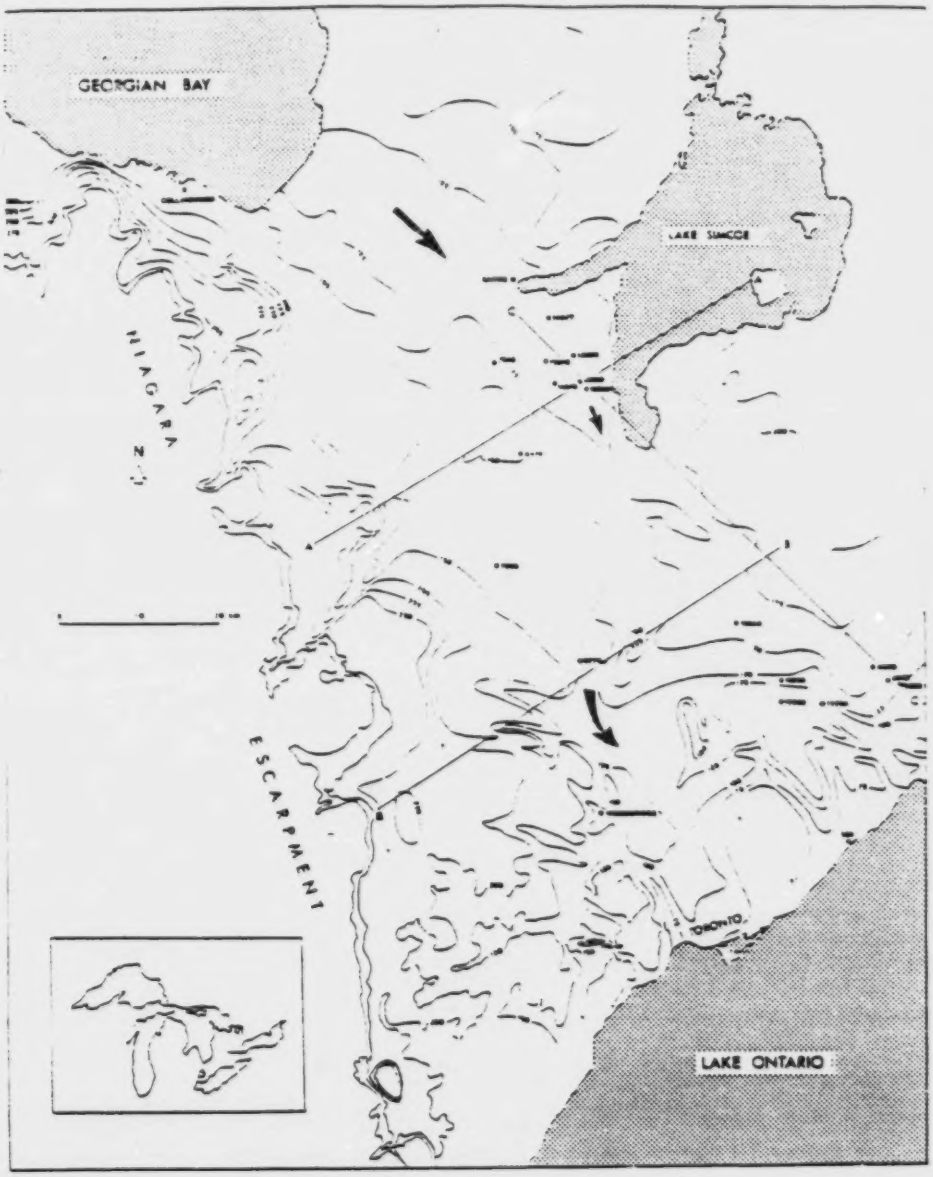

Source: Eyles et al. (1986)

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Delineation of Laurentian Channel

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Figure 2.2

(White 1975), the Newmarket area (Gwyn and DiLabio 1972) and the Alliston area (Gwyn and White 1973). Hewitt's (1969) industrial mineral report shows the surficial geology for Markham and Newmarket.

The Ontario Geological Survey has mapped sand and gravel thickness as part of its Aggregate Resources Inventory. This work consists of a review of previous geological mapping and records of sand and gravel operations supplemented with air photo interpretation and field mapping. Publications relevant to the study include: Papers 23, Town of Caledon, 11, King Township, 3, Town of Whitchurch-Stouffville, 13 Uxbridge Township, 95, Township of Scugog, 94, Town of Newcastle, and 7, Manvers Township.

Mapping by Duckworth (1979) of road cuts and gravel pits remains the most comprehensive work on the interpretation of the depositional history of the western half of the Oak Ridges Moraine, however his work relates only to the upper 10 - 30 m of stratigraphy.

Additional sources of information include consultants' reports dealing with groundwater resources in the area.

While the near subsurface geology is fairly well known in the Oak Ridges Moraine Area, the stratigraphy of the deeper subsurface is not. Domestic water well records on file with Environment Ontario (MOE) provide a large source of information but their use is mostly limited to delineating depth to bedrock and water yielding horizons, and gross lithology. For the most part stratigraphic descriptions are inconsistent and inadequate to allow for the identification and correlation of discrete stratigraphic units.

The MOE described the deeper subsurface of the Oak Ridges Moraine Area in a series of water resource studies, during which several deep test holes were drilled through the moraine to bedrock and give some insight into the deep subsurface lithology in Manvers and Clarke Townships (Funk 1977), in Uxbridge and Whitchurch-Stouffville Townships (Sibul et al 1977), and in King Township (Vallery et al 1982).

The Ontario Geological Survey drilled one borehole to bedrock through the western portion of the moraine to test the oil shale potential of the underlying Georgian Bay Formation (Sado et al 1983).

Deep wells have been drilled to intersect aquifers at depths ranging from 90 - 125 m (300 - 410 ft) for Municipal water supplies for the towns Oak Ridges (Gartner Lee 1988) Aurora (Hydrology Consultants 1977, 1978, International Water Supply 1988, Gartner Lee 1989) and Newmarket (International Water Supply 1976, 1983, Gartner Lee 1986).

The locations of selected deep boreholes to bedrock in the Oak Ridges Moraine Area are shown in Figure 2.3, and stratigraphic logs are presented in Figure 2.4.

2.2.2.2 Depositional History

Despite the uniqueness and extent of the Oak Ridges Moraine, its internal structure is not well known. Drift materials which make up the moraine range in thickness from 152m (500ft) to 244m (800ft) and comprise the thickest sequence of unconsolidated materials in Ontario.

Sibul et al (1977) and Funk (1977) have described the complex assemblage of unconsolidated materials within the moraine as a sequence of drift units, each associated with a glacial advance and withdrawal and each consisting of glacial tills and glaciofluvial and/or glaciolacustrine gravels, sands, silts and clays. These assemblages have been described in terms of stratigraphic sequences some of which have been correlated regionally on the basis of characteristic geophysical response, through the western portion of the study area (Fligg 1983, Eyles et al 1986). Figure 2.5 shows a north-south correlation of the lowermost assemblage which consists of a coarsening upward deltaic sequence of clays, silts and sands known as the Scarborough Formation. Locally, these sands form deep aquifers, such as those found beneath Aurora and Newmarket.

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Location of Deep Boreholes to Bedrock

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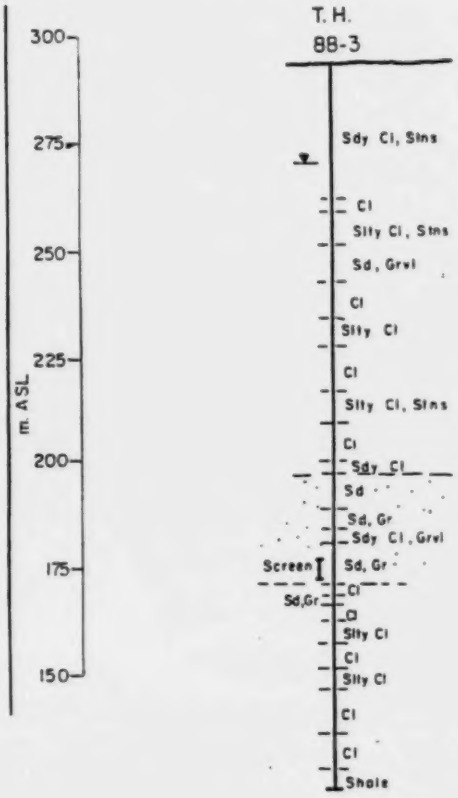
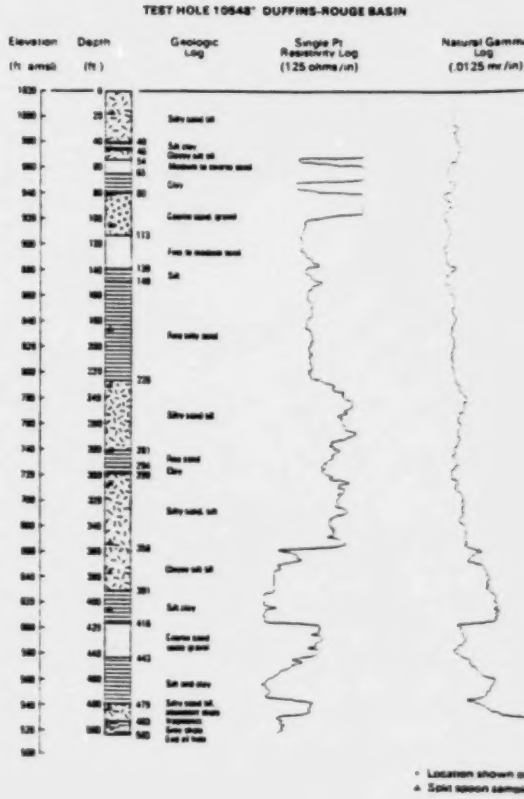
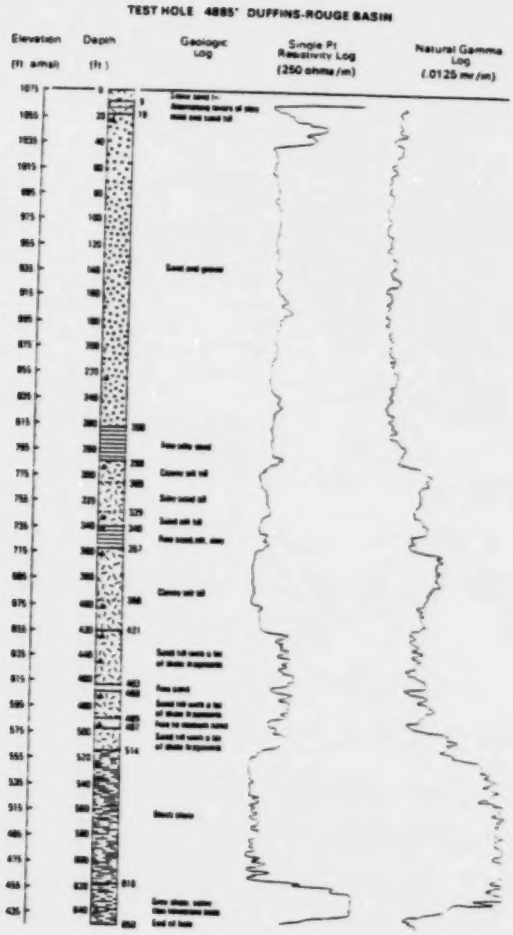
Figure 2.3



Source: Gartner Lee Ltd. (1988)



Source: Sibul et al (1977)



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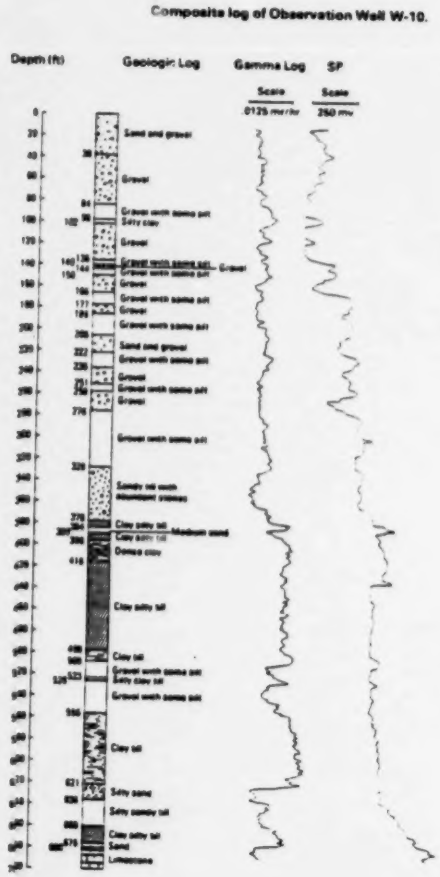

Source: Funk (1977)

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Selected Deep Borehole Logs

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Figure 2.4

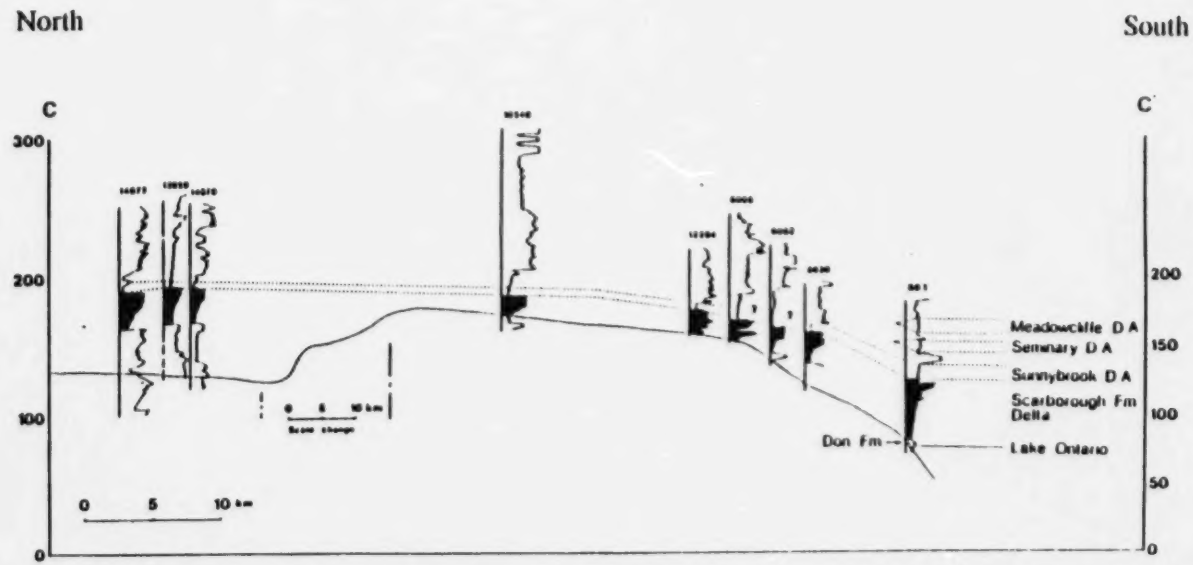

Figure 8 *Subsurface well log correlations of glaciolacustrine units along and across the Laurentian Channel. A coarsening-upwards Scarborough Formation delta body and overlying fine-grained glaciolacustrine diamict assemblage (Sunnybrook; Figures 5, 6) forms a distinct marker horizon. For location of well logs see Figure 3. The Meadowcliffe and Seminary diamict assemblages pinch-out inland with the deltaic sands of the Thorncliffe Formation (Figure 5) which is truncated by varying thickness of grounded ice facies. Geophysical well log data from Figg (1983) and Sibul et al. (1977). Elevations in metres above sea level*

Source: Eyles et al. (1986)

INTERA Technologies	Correlation of the Scarborough Formation	Figure 2.5

Subsequent assemblages of gravels, sands, silts and clays were laid down subject to the advance and retreat of glacial ice in the Lake Ontario and the Lake Simcoe Basins.

Duckworth (1979) describes the depositional history of the upper 30 m in the western half of the Oak Ridges Moraine. The stratigraphy is depicted in a series of cross sections shown in Figure 2.6. During the withdrawal of glacial ice, meltwater became trapped between the retreating lobes, and the emerging moraine, as depicted in Figure 2.7, resulting in the deposition of glacial outwash and deltaic sequences into standing water. Paleocurrent directions indicate that meltwater from retreating ice flowed predominantly to the west and northwest (Duckworth 1979) as indicated in Figure 2.8, resulting in the deposition of increasingly finer grained sequences toward the western end of the moraine. This is illustrated in the cross sections shown in Figure 2.3, where test hole W-10 located at the east end of the moraine shows a considerable thickness of coarse grained sands and gravels compared with test hole 10548 located near Aurora which contains a thick sequence of fine grained silty sands, silts and clays underlying the coarse kame sands and gravels of the moraine. A final advance of the Ontario lobe deposited the Halton Till, a sandy silt till, along the south flank of the moraine. The northerly limit of this advance is marked by a string of kettle ponds and lakes along the moraine axis.

Within this complex stratigraphy lie shallow and deep aquifers which provide a source of water for domestic, municipal and stock consumption as well as irrigation, recreation and industrial purposes.

2.3 SOILS

Soils within the study area are described in a series of County soil reports which cover the counties of Durham (Webber and Morwick 1946), Ontario (1957), York (Hoffman and Richards 1955) and Peel (Hoffman and Richards 1953) and are summarized in Plate 2. For simplicity, soils have been differentiated as three basic types: (i) sand, sandy loam, (ii) silt, silt loam or loam and (iii) clay loam. Almost without exception, the soils developed within the Oak Ridges Moraine Area belong to the Grey Brown Podzolic Great Soil Group which are developed

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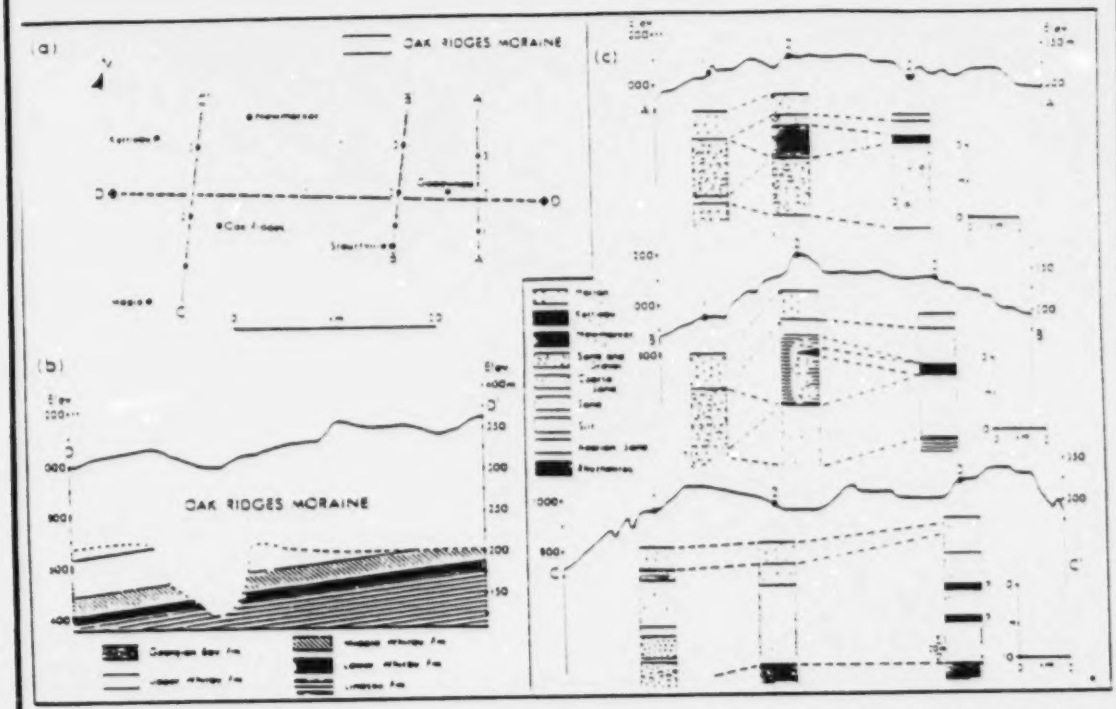

FIG. 4. Cross-sectional profiles and general stratigraphy at the western end of the Oak Ridges Moraine. (*a*) Location of the profiles and sections. (*b*) Profile showing the relationship between the Oak Ridges Moraine and the underlying bedrock; note the presence of the large bedrock valley transverse to the moraine south of Newmarket. (*c*) Profiles AA', BB', and CC' with superimposed stratigraphic sections.

Source: Duckworth (1979)

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Stratigraphic Relationship for the Western End of the Oak Ridges Moraine

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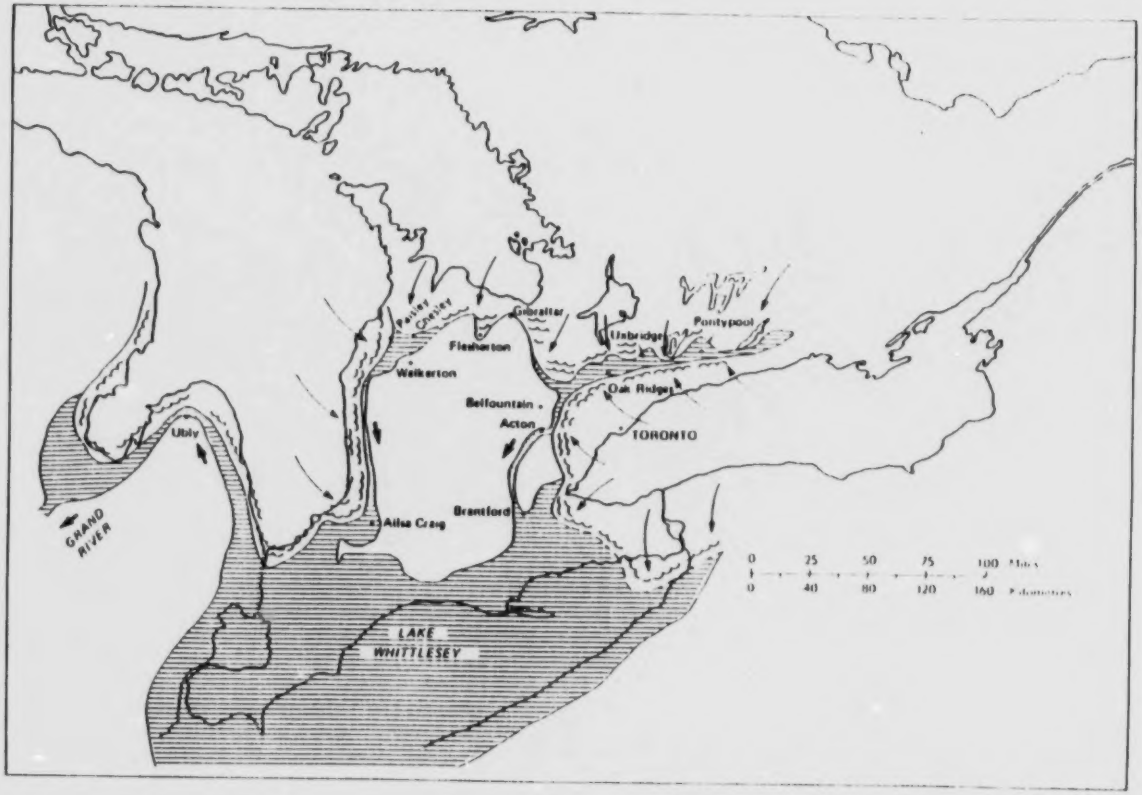
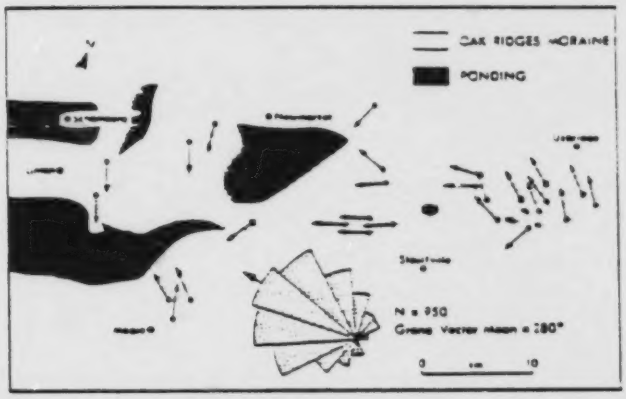
Figure 2.6



Source: Chapman and Putnam (1984)

INTERA Technologies	Damming of Glacial Meltwater Between Ontario and Simcoe Ice Lobes	Figure 2.7



Source: Duckworth (1979)

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Paleocurrent Directions for the Western End of the Oak Ridges Moraine

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Figure 2.8

from calcareous materials. The soils reflect the underlying parent materials and typically are slightly acid to slightly alkaline, well drained throughout, contain little organic material and, in those areas where the slope is reasonable to allow farming activity, require additions of manure and fertilizer to maintain fertility. The soils contain poorly developed or non-existent B horizons in Durham County to the east but B horizons become somewhat better developed in Peel County to the west as grain size decreases and organic content rises. Soils are droughty and usually hilly to steep and, since they are susceptible to wind erosion, should be maintained with some sort of cover. Typical tree stands include red and white pine, red oak, hickory, white birch and sugar maple.

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III HYDROLOGIC FEATURES OF THE STUDY AREA

3.1 HYDROLOGIC BUDGET

The hydrologic budget is an accounting of the water that enters and leaves the watershed, and is often quantified in basin studies. In a simplified steady state system, where changes in groundwater and surface water storage are essentially zero and groundwater inflows are equal to groundwater outflows, a water balance equation can be written as:

$$P = E + Q \qquad (1)$$

where P = precipitation
E = evapotranspiration
Q = average annual runoff

The average annual runoff Q, consists of a groundwater component, Qg, also known as baseflow, and a surface water component, Qs. Equation (1) can be rewritten as:

$$P = E + Qg + Qs \qquad (2)$$

The various components of the equation can be measured in the field or calculated.

Precipitation as rain and snow is measured directly in the field using precipitation gauges. Measured precipitation from stations in the area has been previously given in Table 2.1.

Evapotranspiration, which is the combined discharge of water evaporated from the ground surface and that which is transpired by plants, can be measured in the field or calculated. Evapotranspiration is often calculated as potential evapotranspiration (PE) and is the evapotranspiration that would occur if there was sufficient soil moisture to meet demand. It is greater than actual evapotranspiration (AE) in recharge areas but may approach (AE) in discharge areas (Freeze and Cherry 1979). Evapotranspiration losses are minimal during winter, but during

the summer months, evapotranspiration can exceed precipitation leading to a loss of soil moisture. Actual evapotranspiration for the study area ranges from 53.3 - 55.9 cm (21 -22 in.) while potential evapotranspiration has been calculated at between 55.9 and 58.4 cm (22 - 24 in.) (Kaye 1986). Roulet (1989a) calculated evapotranspiration in the Duffins Creek headwater area to be 55.4 cm (21.8 in.) for the period 1987-1988. Funk (1977) measured actual evapotranspiration as 56.5 cm (22.2 in.) for eastern Durham County. The values for actual evapotranspiration in the moraine area are generally slightly higher than the value for actual evapotranspiration for the Lake Ontario Basin of 53.3 cm (21 in.) (Kaye 1986). Evapotranspiration data are summarized on Table 3.1.

The average annual runoff consists of a surface runoff or overland flow component, subsurface stormflow, and a groundwater runoff or baseflow component (Freeze and Cherry 1979). These components are illustrated in Figure 3.1. The total stream runoff can be measured as stream discharge over time, and recorded as a hydrograph at gauging stations situated throughout a drainage basin. Separation of the groundwater component from the surface water component on the hydrograph is carried out by means of hydrometric or geochemical techniques.

Calculations of baseflow from various sub-basins within the study area are given in Table 3.2.

Baseflow, or the groundwater runoff component, was calculated by Funk (1977) for two watersheds, portions of which were within the Oak Ridges Moraine. For the moraine portion of each wastershed, baseflow was calculated as 60.3 percent of total streamflow for Bowmanville Creek and 88.2 percent for Wilmot Creek. Calculations were also carried out on portions of these same creeks for baseflow within the south slope of the moraine and these values ranged from 54.9 percent to 70.1 percent of total streamflow respectively. Roulet (1989a) calculated baseflow contribution to a headwater stream in Duffins Creek as 94 percent.

Baseflow calculations by Sibul et al (1977) were calculated for the central and lower reaches of the Duffins Creek and Rouge River basins and ranged, as a percentage of total

TABLE 3.1

Evapotranspiration in the Oak Ridges Moraine Area

STATION	POTENTIAL EVAPOTRANS-PIRATION	ACTUAL EVAPOTRANS-PIRATION	PERIOD	REFERENCE
Lake Ontario Basin	58.4-61.0 cm (23-24 in.)	53.3 cm (21 in.)		Kaye (1986)
Oak Ridges Area	55.9-58.4 cm (22-23 in.)	53.3-55.9 cm (21-22 in.)		Kaye (1986)
Duffin Creek Headwater		55.4 cm (21.8 in.)	1987-88	Roulet (1989a)
		50-60 cm (19.7-23.6 in.)	long term	Roulet (1989a)
Durham County		56.5 cm (22.2 in.)	long term	Funk (1977) (ave. of 2 calculations)

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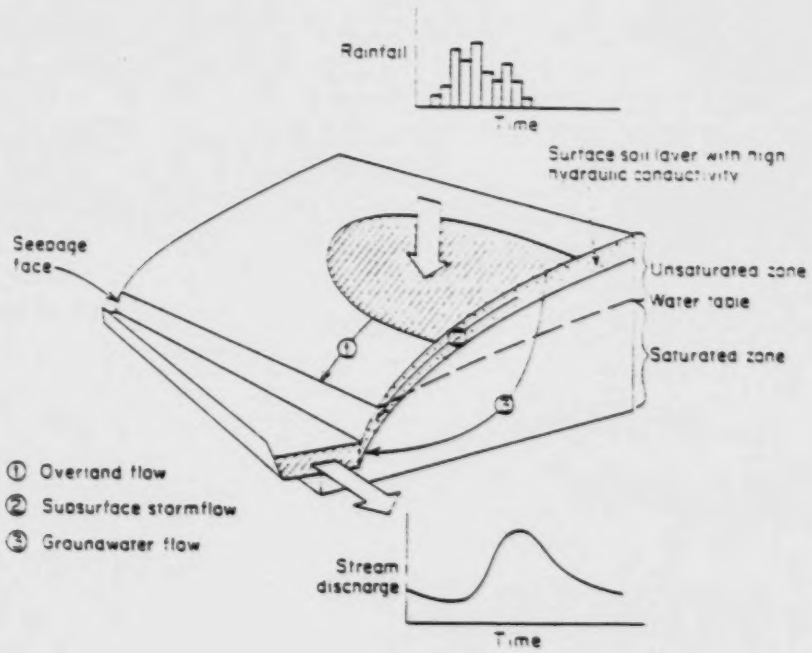

Source: Freeze and Cherry (1979)

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Components of Stream Runoff

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Figure 3.1

TABLE 3.2

Baseflow Calculations for Selected Watersheds in the Oak Ridges Moraine Area

Watershed	Station	Period	Baseflow	Percentage of Total	Reference
Bowmanville Creek (Oak Ridges Moraine)	B1	1967-1974	0.86 cfs (5.85 in.)	60.3	Funk (1977)
(Oak Rdges-Southslope)	B4	1967-1973	9.10 cfs (11.22 in.)	62.5	Funk (1977)
Wilmot Creek (Oak Ridges Moraine)	W1	1967-1972	3.68 cfs (10.86 in.)	88.2	Funk (1977)
Soper Creek (Oak Ridges-Southslope)	S1	1968-1972	1.45 cfs (10.88 in.)	70.1	Funk (1977)
(Oak Ridges-Southslope)	S2	1967-1972	3.97 cfs (8.82 in.)	54.9	Funk (1977)
Duffins Creek (Oak Ridges Moraine-headwater)		1987-1988	16 L/S	94	Roulet (1989a)
(Lake Iroquois Plain)	2HC006	1946-1970	48 cfs	50	Sibul et al (1977)
West Duffins Creek (Central Till Plain)	2HC026	1964-1970	10.7 cfs	37	Sibul et al (1977)
(Lake Iroquois Plain)	2HC019	1962-1970	23 cfs	61	Sibul et al (1977)
Rouge River (Central Till Plain)	2HC022	1962-1970	13 cfs	27	Sibul et al (1977)
(Lake Iroquois Plain)	2HC015	1957-1961	14 cfs	30	Sibul et al (1977)
Little Rouge Creek (Central Till Plain)	2HC028	1964-1970	7.4 cfs	32	Sibul et al (1977)
(Lake Iroquois Plain)	2HC014	1957-1963	7.2 cfs	28	Sibul et al (1977)
Holland and Black Rivers		1970-1976	3 in.	34	Vallery et al (1982)

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streamflow, from 37 - 61 percent in the Duffins Creek basin and from 27 - 30 percent for the Rouge River basin.

Baseflow calculations by Vallery et al (1982) over the entire Holland and Black River watersheds amounted to approximately 34 percent of total streamflow.

3.2 HYDROGEOLOGY

For the purposes of this report, the aquifer systems in the Oak Ridges Moraine Area are divided into shallow systems and deep systems. While there is no well defined stratigraphic break between the two systems, they do reflect generally the distribution of coarser grained materials (sands and gravels) which are separated by fine grained sequences of tills and glaciolacustrine silts and clays. In this report, the shallow groundwater flow systems are referred to as moraine aquifer complexes, and generally describe the occurrence of groundwater at depths up to about 250 ft (76 m) deep and occurring at elevations generally above 750 ft (229 m) a.m.s.l. Deeper systems describe groundwater supplies at Newmarket, Oak Ridges and Aurora which occur at depths of between about 300 to 400 ft (91 to 122 m) and at elevations below about 620 ft (189 m) a.m.s.l.

Other municipal groundwater supplies within the moraine area include Caledon East, Inglewood, Mono Mills, Palgrave, King City, Uxbridge and Stouffville. These groundwater supplies are not discussed in this report, but information about them exists on file with MOE.

3.2.1 Shallow Groundwater Flow Systems

3.2.1.1 Extent of Moraine Aquifer Complexes

The Geological Survey of Canada conducted the first systematic investigation of groundwater resources in the area in 1936 and 1937, in response to serious water shortages brought about by low rainfall. The results of the investigation, which covered roughly 800 mi^2

in York, Peel and Ontario Counties, found that those private wells that went dry were likely to be very shallow (less than 20ft deep) and/or bottomed in low yielding till. A significant number of private wells, 71-89 percent in King, Vaughan, Albion, Markham, Pickering and Uxbridge Townships, were less than 40ft deep, (Hainstock et al 1948a, 1948b, 1948c, Caley et al 1948a, b, Gadd 1950) while in Whitchurch Township, deeper wells were required to intersect adequate groundwater supplies at depths of 80 ft or less (Hainstock et al 1952).

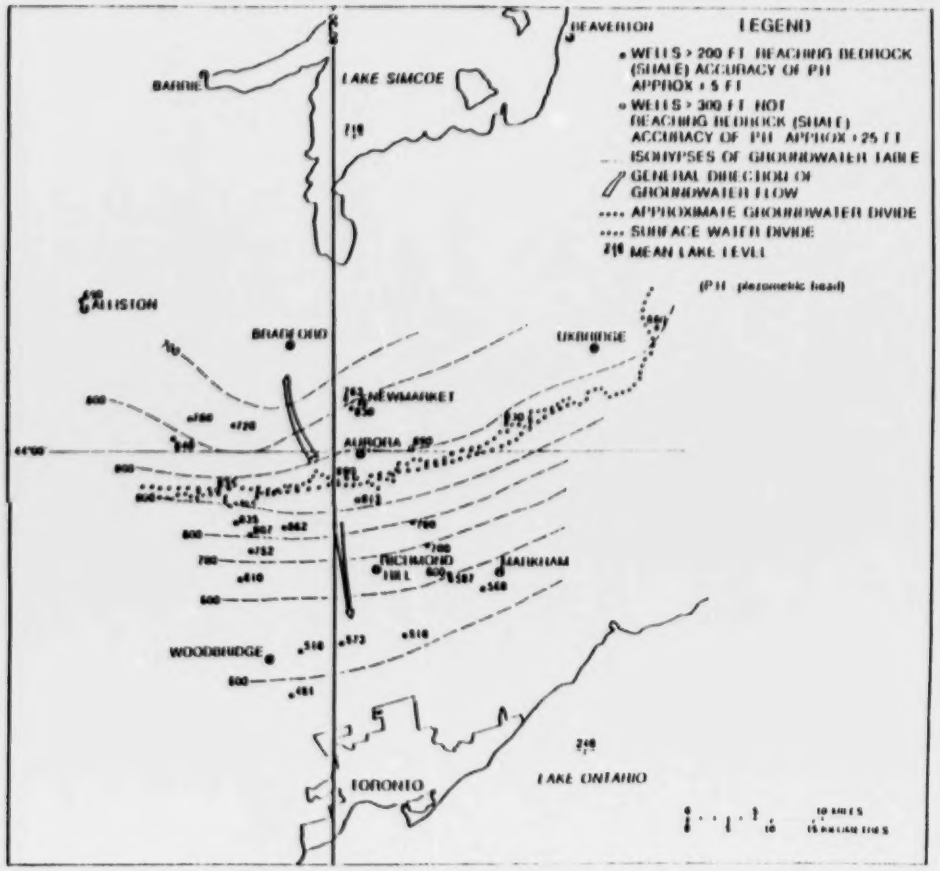
Aquifers in the Oak Ridges Moraine, and within the till plain to the south of the Oak Ridges Moraine, were described as consisting of irregularly shaped lenses of sand and gravel.

The irregular geometry of these aquifers reflects their complex depositional history associated with the advance and withdrawal of glacial ice margins; and, coupled with the hummocky topography of the moraine gives rise to complex groundwater flow regimes consisting of local and more regional flow systems (Freeze and Cherry 1979).

A groundwater divide exists beneath the Oak Ridges Moraine Area which conforms with the surface drainage divide (Haefeli 1970) and is illustrated in Figure 3.2. North of the divide groundwater flows toward Lake Simcoe, while south of the divide groundwater flows toward Lake Ontario.

Several aquifers and aquifer systems have been mapped locally within the Oak Ridges Moraine Area, on the basis of water well records, and the occurrence of groundwater at similar elevations. The largest aquifer, called the Oak Ridges Aquifer System, has been identified and mapped by Turner (1977) as extending from Durham Region in the east to just west of Aurora. Sibul et al (1977) identified the Oak Ridges Aquifer Complex within the northern portion of the Duffins Creek-Rouge River Basin and Vallery et al (1982) indicated the extent of the Oak Ridges Aquifer Complex within the Holland and Black River Basins.

Vallery et al (1982) also identified a Kame Outwash Aquifer Complex extending from Aurora across the southernmost portion of the Holland-Black River Basin and into the adjoining



Source: Haefeli (1970)

INTERA Technologies	Groundwater and Surface Water Divides in the Oak Ridges Moraine Area	Figure 3.2

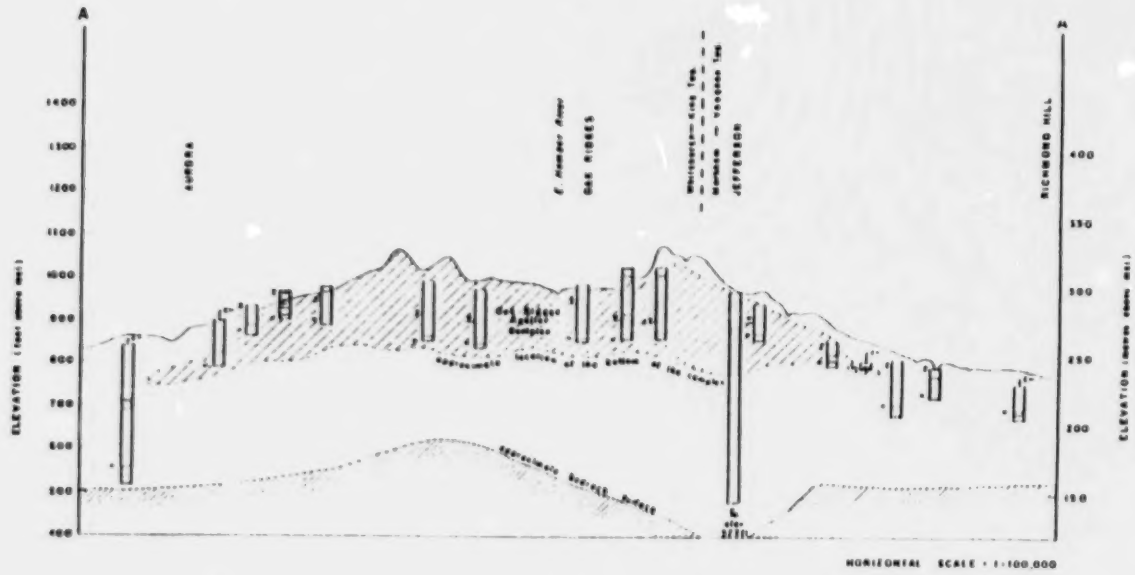
Upper Nottawasaga River Basin. The nature of the aquifer materials, and the top of the water bearing formation in this complex are similar to those of the Oak Ridges Aquifer Complex as mapped by Turner (1977). In this report, to avoid confusion, formal aquifer names will be dropped in favour of the generic term moraine aquifer complex.

In Peel Region, groundwater resources were evaluated by Hickenbotham (1979). No attempt was made to identify the extension of moraine aquifer complex into Peel, and groundwater probability was interpreted in terms of depths to water rather than elevations to the top of water bearing formations.

Lenses of permeable sands and gravels within the moraine aquifer complex are reported from drillers' logs up to 50 - 60 m in thickness. The average saturated thickness within the moraine aquifer complex is roughly 15 m (Sibul et al 1977, Vallery et al 1982).

Along the ridge of the moraine, which roughly defines the groundwater divide, permeable sands and gravels occur at surface and extend to the water table. This condition gives rise to aquifers which are unconfined, since the equilibrium or static water level is defined by the water table, and the water is not under artesian pressure. At depth within the aquifer complex, lenses of fine silt and clay which have a lower permeability and are known as aquitards, create conditions of perched water tables and confining conditions. Perched water tables are formed when an aquitard of limited extent occurs above the regional water table and traps infiltrating water to form a local or perched water table. Confined conditions occur when an aquifer is overlain by an aquitard and causes the equilibrium water level to rise to a level above the top of the water bearing horizon. In this situation, groundwater is under artesian pressure. If the equilibrium water level is located above ground surface, then the well will flow and is called a flowing artesian well.

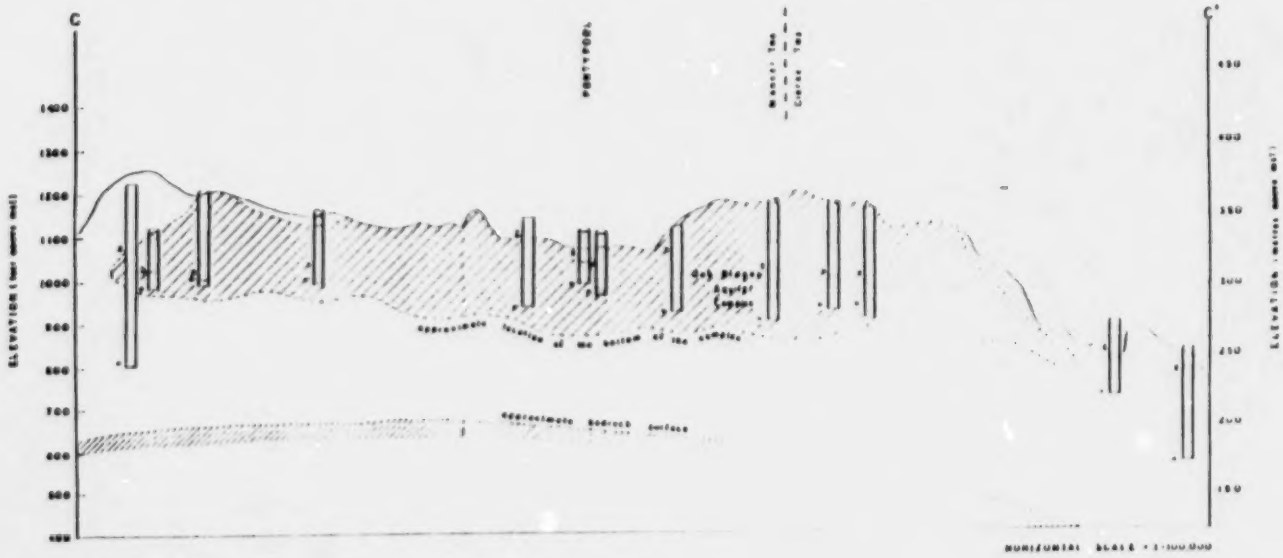
A series of north-south cross sections through the moraine aquifer complex is shown in Figure 3.3 a and b. Figure 3.4 is a north-south cross section through the south slope area of the



CROSS SECTION A-A'

Source: Turner (1977)

INTERA Technologies	Cross Section A-A' Through the Oak Ridges Moraine Between Aurora and Richmond Hill	Figure 3.3a



CROSS SECTION C-C'

Source: Turner (1977)

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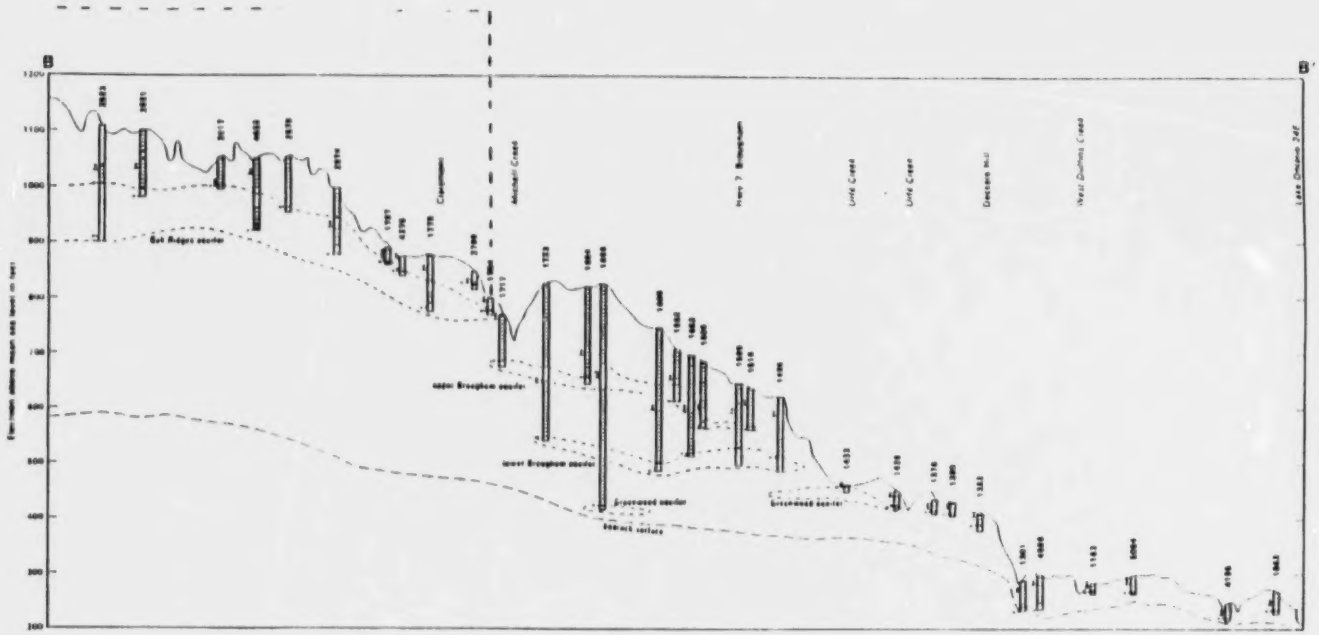
Cross Section C-C' Through the Oak Ridges Moraine at Pontypool

Figure 3:3b

limit of Oak Ridges Moraine Area



Source: Sibul et al (1977)

INTERA Technologies	North South Cross Section Through Duffins Creek Drainage Basin	Figure 3.4

Duffins Creek drainage basin, showing the relationship between the moraine aquifer complex and local aquifers of the south slope.

Groundwater yields within the moraine aquifer complex are generally adequate for domestic and stock requirements, providing yields of 0.5 - 5 litres/second (L/s) (Vallery et al 1982, Sibul et al 1977). High capacity wells for municipal and industrial purposes are capable of producing up to 53 L/s.

The extent of the moraine aquifer complex is shown on Plate 2.

3.2.1.2 Groundwater Flow Directions

In aquifer complexes, groundwater flow occurs in three dimensions, and consists of both horizontal and vertical flow components. Groundwater flow in uniform materials occurs in a direction perpendicular to the contours of hydraulic head. Contours of hydraulic head determined from static level elevations measured in numerous domestic wells in the area are plotted on Plate 2, and arrows depict directions of horizontal groundwater movement. Vertical components of flow, not shown on Plate 2 are downward in recharge areas, and upward in discharge areas.

Regionally, within the moraine aquifer complex, groundwater recharges downward and laterally away from the groundwater divide. Locally, groundwater flow is toward headwater streams. A component of groundwater movement within the moraine aquifer complex recharges the deeper groundwater system which partly underlies the moraine aquifer complex and is the source of water for municipal supplies in Oak Ridges, Aurora and Newmarket.

The horizontal groundwater flow velocity was calculated for a small portion of the moraine aquifer complex near Musselman Lake. Kaye (1986 estimated a velocity of 65 - 90 m/yr, based on the movement of a chloride contaminated plume associated with a landfill site.

A summary of hydraulic properties of aquifers in the Oak Ridges Moraine Area is given in Table 3.3.

The following is a discussion of some of the terms in Table 3.3. Hydraulic conductivity can be thought of in simple terms as the ease with which a fluid can move through a porous material. It is a function of both the permeability of the material as well as properties of the fluid which in this case is water. Coarse grained materials such as sands and gravels have higher hydraulic conductivities than silts and clays. Hydraulic conductivities for sands typically range from 10^{-5} - 10^{-2} metres/second (m/s) while hydraulic conductivities for silts may range from 10^{-9} - 10^{-5} m/s (Freeze and Cherry 1979).

Transmissivity is simply the product of the hydraulic conductivity and the saturated thickness of the aquifer. Units are expressed as m^2/s or m^2/day, however, in some reports, the units are reported as Imperial gallons per day per foot or Igpd/ft. Transmissivities of $0.014 m^2/s$ or about 1200 m^2/d (80,000 Igpd/ft) or more indicate aquifers with an excellent potential for producing municipal groundwater supplies.

Storativity, sometimes known as the storage coefficient is defined as the volume of water that is released per unit surface area of aquifer for each unit drop in hydraulic head. This term, which does not have any units, is used to describe a property of confined aquifers.

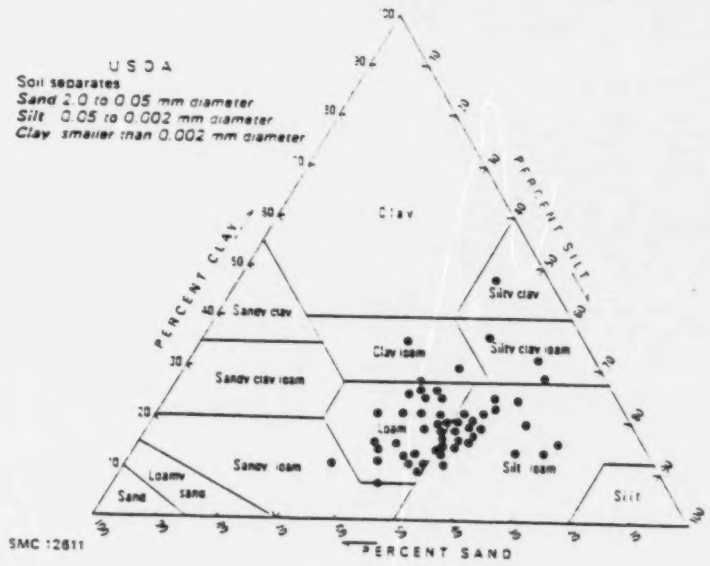
3.2.1.3 Groundwater Recharge

Groundwater recharge occurs over a considerable portion of the Oak Ridges Moraine Area, but rates of infiltration are extremely variable due to the variability of surface materials (Yakutchik personal communication). The Halton Till, which covers the south flank of the moraine area ranges in texture from a sandy loam to a silty clay and in places appears to be very permeable (Westgate personal communication). A grain size composition for the Halton till indicate it to be mostly a loam to silt loam as shown in Figure 3.5. Where the till is fine grained, recharge is impeded and confining conditions exist, but detailed mapping in the vicinity

Table 3.3

Hydraulic Properties of Moraine Aquifer Complex in the Oak Ridges Moraine Area

Transmissivity (m^2/day)	Storativity	Hydraulic Conductivity (m/s)	Reference	Comments
1210	1.6×10^{-10}		Haefeli (1970)	pumping test Richmond Hill
30 - 50	-		Haefeli (1970)	calculated from specific capacities from shallow wells
164	4.4×10^{-5}		Sibul et al (1977)	industrial well Claremont
121	2.5×10^{-4}		Sibul et al (1977)	Stouffville Municipal well #8
57			Sibul et al (1977)	calculated from short term pump test data given in MOE water well records
1.1			Funk (1977)	pump test Oak Ridges Upper Drift Unit
1.1	6.4×10^{-4}		Funk (1977)	pump test South Slope Upper Drift Unit
		5×10^{-5} - 6×10^{-3}	Funk (1977)	grain size analysis



Source: White (1975)

Drawn by	Date	Grain Size Composition for Halton Till
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INTERA Technologies		Figure 3.5

of Musselman Lake suggests the occurrence of "windows" of higher permeability materials within the Halton Till (Kaye 1986). These "windows" of recharge can perhaps be identified from depressions in the water table, but this type of analysis would require very detailed investigation including the installation of monitor wells and the measurement of water levels. North of Musselman Lake, north of the limit of Halton Till, and extending west to Aurora, the moraine aquifer complex is largely unconfined, (Yakutchik personal communication) and is an area of relatively rapid recharge. These unconfined portions of the moraine aquifer complex should be considered as hydrologically significant and should be identified by means of a detailed review of well logs, hydrogeological reports and other available information.

Several studies have attempted to identify areas of significant recharge within the moraine area. Ecologistics (1982) utilized surficial geology maps, soil maps, and the identification in well drillers' logs of sands and gravels to identify areas of significant infiltration in portions of Uxbridge Township and the Town of Whitchurch Stouffville.

James F. MacLaren Ltd. (1975) identified areas of high recharge potential in the township of King and in the towns of Aurora, and Whitchurch-Stouffville on the basis of static water level elevations (potentiometric surface elevations). However, both of these studies failed to consider induced recharge from downward gradients of hydraulic head in the vicinity of pumped wells.

The identification of specific areas of significant recharge for the purposes of applying development controls requires a comprehensive evaluation of the entire Oak Ridges Moraine Area and is beyond the scope of this study.

Water that is rapidly recharged is younger in age than water that is slowly recharged. Tritium, a radioactive isotope, which is naturally present in the earth's atmosphere and was added in large amounts to the atmosphere during atmospheric bomb testing, starting after 1953, is commonly used to date groundwater as being pre-bomb or post-bomb water. Concentrations

of tritium in groundwaters from the central portion of the moraine complex indicates that groundwater has recharged in the Oak Ridges Aquifer since 1953 (Howard and Beck 1986, Proulx and Farvolden 1989).

Recharge and discharge conditions within the Duffins Creek and Rouge River drainage basins are illustrated in Figure 3.6.

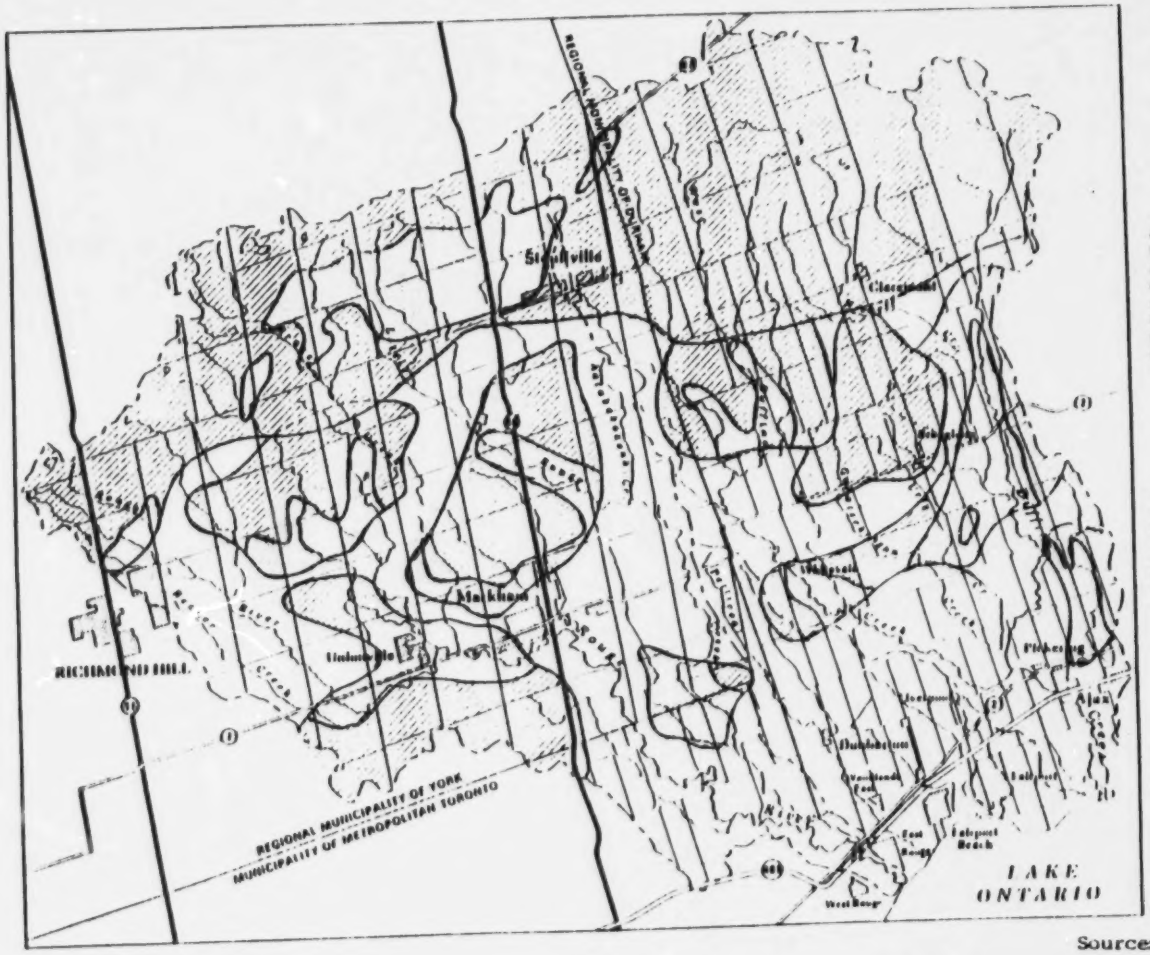
3.2.1.4 Groundwater Discharge

Groundwater discharge provides baseflow to streams which sustains streamflow between precipitation events. Within the upper reaches of stream catchment areas in the moraine area, groundwater discharge is significant in maintaining a cold water stream zone.

Along the northern and southern lower slopes of the Oak Ridges Moraine, groundwater locally seeps and discharges to stream valleys where upward gradients in the zone of saturation intersect the ground surface. These areas of discharge are commonly identified as small wetland areas within headwater basins (Roulet 1989a), and are discussed more fully in section 3.3. Areas of groundwater discharge within the Duffins Creek-Rouge River drainage basins are shown in Figure 3.6, which shows the flowing well area northwest of Stouffville, a major zone of groundwater discharge in the Rouge River basin. Figure 3.7 is a cross section through the flowing well zone and shows the location of flowing wells at the major break in slope at the ground surface along the south flank of the moraine. Funk (1977) reports that wells completed near the break in topographic slope show upward gradients indicating groundwater discharge conditions.

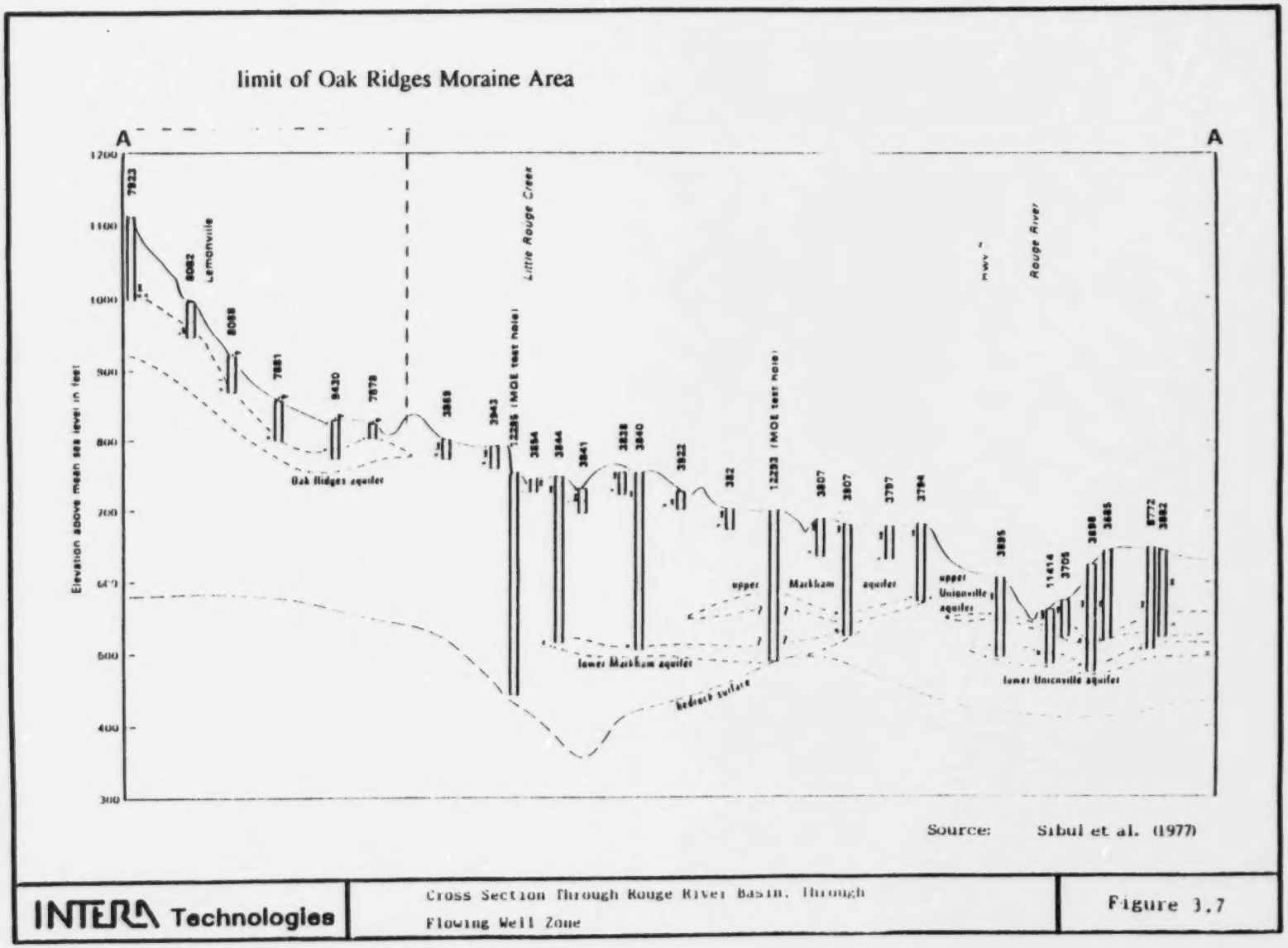
3.2.1.5 Groundwater Quality

Groundwater quality within the moraine aquifer complex is generally good to excellent. Groundwaters are hard and predominantly calcium bicarbonate in character (Sibul et al 1977, Funk 1977, Vallery et al 1982, Beck 1985, and Howard and Beck 1986).


REGIONAL MUNICIPALITY OF YORK
MUNICIPALITY OF METROPOLITAN TORONTO
LAKE ONTARIO
LEGEND
recharge
Area where the elevations of water levels in shallow wells are higher than the piezometric surface in the underlying aquifer. This indicates a downward movement of ground water in the saturated zone above the aquifer
discharge
Area where the elevations of water levels in shallow wells are lower than the piezometric surface in the underlying aquifer. This indicates an upward movement of ground water in the saturated zone above the aquifer.

Source: Sibul et al (1977)

INTERA Technologies	Areas of Recharge and Discharge in the Rouge River Duffins Creek Basin	Figure 3.6



Source: Sibul et al. (1977)

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Cross Section Through Rouge River Basin, Through Flowing Well Zone

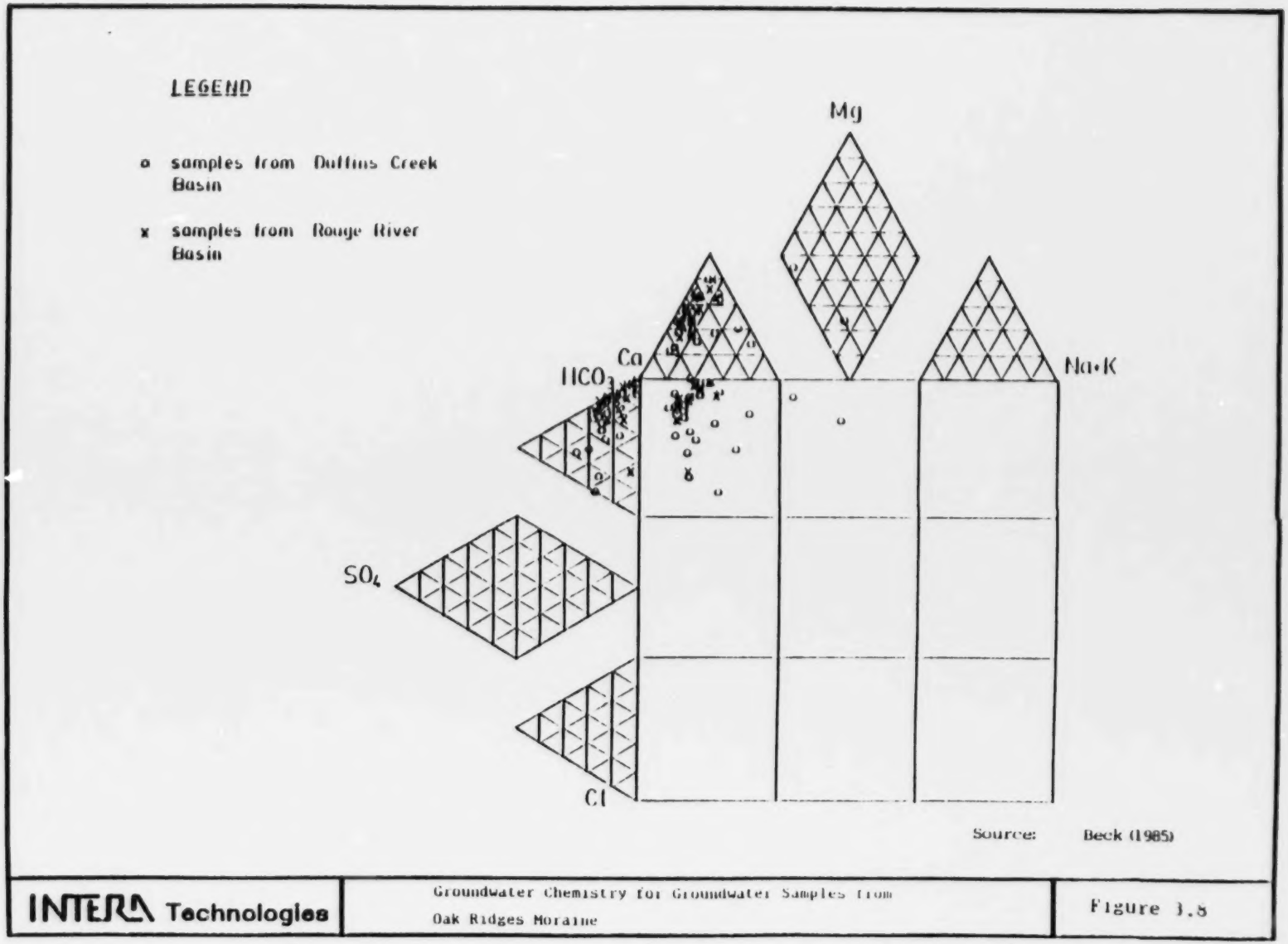
Figure 3.7

While the general water quality is good, unconfined aquifers particularly those that are at a shallow depth are susceptible to contamination. Commonly occurring contaminants include road salt, as indicated by high chloride levels, and nitrate from septic systems and manure and fertilizer additions from agricultural activity.

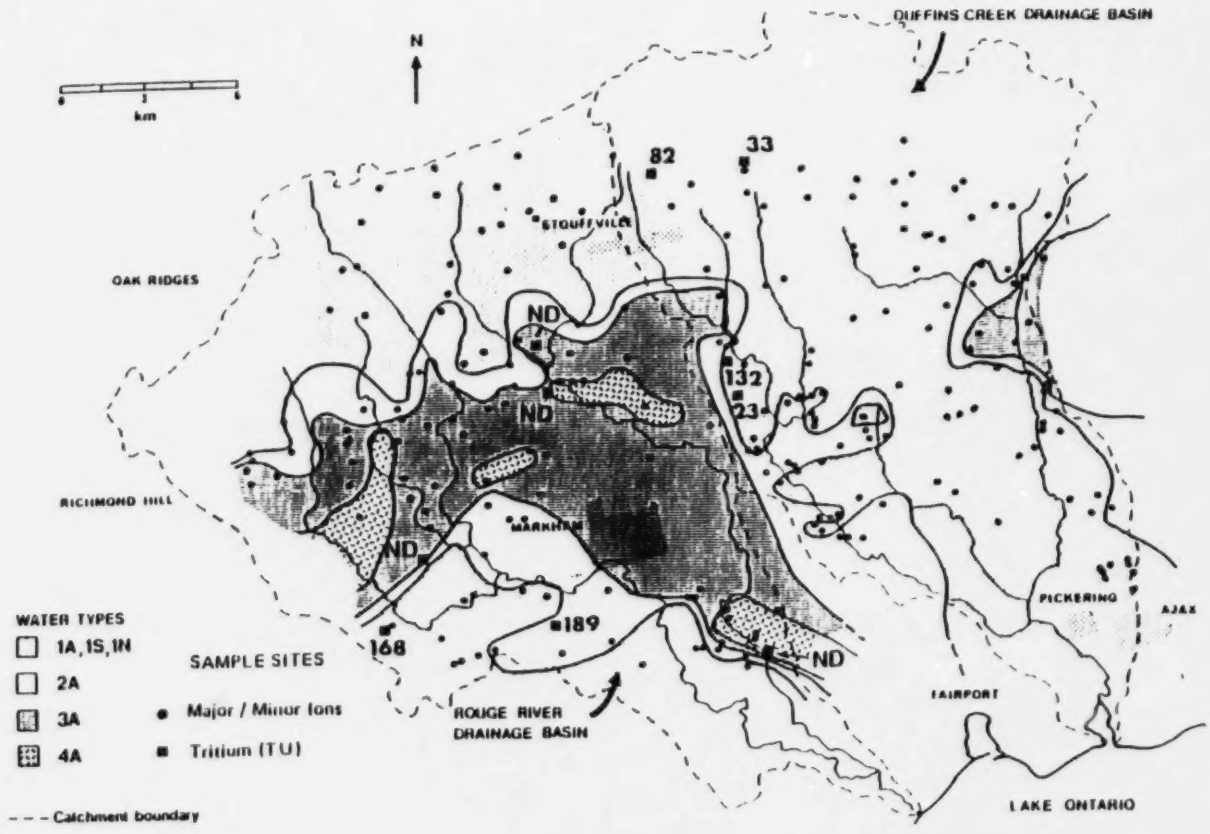
A Durov diagram, which represents water chemistry in terms of its major ions, is shown for samples taken from the southern portion of the moraine aquifer complex in Figure 3.8. It is interesting to note that those samples taken from the moraine aquifer complex within the Duffins Creek drainage basin show more scatter than those samples taken from the Rouge River drainage basin. The Duffins Creek basin samples show higher ranges for sodium and chloride which is most likely attributable to contamination from the addition of road salt. The difference in chemistries from groundwaters evolving within the two different basins is shown in Figure 3.9.

Four water types are identified in Figure 3.9 based on major and minor ion chemistry, which illustrate the degree of chemical evolution of the groundwater (Howard and Beck 1986). Type 1 waters are typical of recharge areas, and, when uncontaminated, typically contain relatively low levels of sodium, chloride, fluoride and iodide. With increasing age of the groundwater, natural processes such as mineral dissolution, precipitation and ion exchange cause chemical changes to the groundwater. Type 2, 3 and 4 groundwaters are progressively older as indicated by tritium levels and show progressive increases in concentrations of sodium, chloride, fluoride and iodide and decreases in calcium.

In Figure 3.9, the difference in groundwater chemistries between the two adjascent basins is striking. In Duffins Creek, groundwaters are predominantly Type 1 and seldom evolve past Type 2, whereas in the Rouge River basin, groundwaters evolve progressively from Type 1 to Type 3 and 4 waters. The chemical differences in groundwaters from the two basins reflect differences in the nature and distribution of surficial materials which allow relatively rapid recharge over much of the Duffins Creek basin and the moraine portion of the Rouge River basin and more restricted recharge in the Rouge River basin south of the moraine.



INTERA Technologies	Groundwater Chemistry for Groundwater Samples from Oak Ridges Moraine	Figure 3.8



Source: Howard and Beck (1986)

INTERA Technologies	Groundwater Types in the Duffins Creek Rouge River Drainage Basins	Figure 3.9

Table 3.4 gives representative chemistries for samples taken within the moraine aquifer complex. Flowing wells, sampled from confined aquifers within the complex show levels of chloride generally less than 5mg/L and nitrate levels of less than 10mg/L (as NO_3-N) while unconfined aquifer samples show levels of chloride greater than 5mg/L and nitrate levels greater than 10mg/L (Beck 1985). The difference in water quality between confined and unconfined aquifers illustrates the potential for contamination of unconfined aquifers.

3.2.2 Deep Groundwater Flow Systems

Deep aquifers provide a source of groundwater for major municipal supplies in Newmarket, Aurora and Oak Ridges. These aquifers occur in the lower portion of the stratigraphic sequence between the base of the Oak Ridges Aquifer as mapped by Turner (1977) and the top of bedrock, and lie within the broad north-south trending bedrock channel described in Section 2.2.1 (see Figure 2.2, 2.6). Bedrock valleys have been identified as favourable areas to explore for future municipal supplies (Gartner Lee 1986, 1988).

A review of municipal well reports indicates that the deeper aquifers occur at depths ranging from about 290 ft - 340 ft (88 to 104 m) for Aurora, 330 ft - 370 ft (100 to 113 m) for Newmarket, and about 375 ft - 410 ft (114 to 125 m) for Oak Ridges and compares with maximum depths of about 250 ft (76 m) for the shallower moraine aquifer complexes. The important deep aquifer sands and gravels are commonly found at an elevation ranging from 590 ft - 620 ft (180 to 189 m) a.m.s.l. (J. Hubey, personal communication).

Pumping tests indicate that wells located in deep aquifers in the same general area are hydraulically connected, but strong boundary conditions suggest that these aquifers have a limited lateral extent (Haefeli 1970, International Water Supply 1988). Waters in the deep aquifers are old and have been isotopically dated at between 1800 and 4000 years (Gartner Lee 1988). This water has percolated through the overlying fine grained sediments due to the difference in

Table 3.4

Representative Groundwater Chemistry for Moraine Aquifer Complexes

Well No.	Depth (ft)	Ca	Mg	Na	K	HCO_3	SO_4	Cl	NO^3-N	Fe	Source
(a) **Shallow Aquifers**											
74	60	66	17	6	1.2	237	25	6	-	-	1
6662	70	53	18	8	1.0	270	6	5	<0.1	0.20	2
8395	66	93	17	5	1.5	281	36	11	2.2	0.05	3
7690	127	82	16	3	1.3	296	29	2	<0.2	0.08	3
9210	22	99	15	5	1.4	357	22	4	<0.1	0.15	4
(b) **Deep Aquifer**											
7692	223	67	11	3	1.3	255	1	1	<0.2	2.0	3
8724	240	28	16	28	1.0	237	3	2	<0.1	0.45	4

note: all concentrations in mg/L

Sources:
1 Funk (1977)
2 Wang (1986)
3 Sibul et al (1977)
4 Vallery et al (1982)

hydraulic head between the surface and the deeper aquifer. The vertical downward gradient is increased even more by the pumping of the municipal wells inducing leakage from the overlying sediments.

On the basis of an estimated annual infiltration rate of 30mm to the deep aquifers, each square kilometer of deep aquifer is capable of providing $80m^3$/day (Gartner Lee 1988) without causing a decline in water levels. This number provides a very rough indication of the maximum daily rate of groundwater removal from all sources in the deep aquifers which can be sustained by natural recharge.

Table 3.5 lists groundwater production from municipal wells in the deep aquifers. It is obvious from the data, that over the past ten years, groundwater demand has risen significantly. Presently in York Region there is concern about groundwater withdrawal exceeding recharge, and the possible interference with municipal supplies from the withdrawal of groundwater from the deep aquifers used to irrigate golf courses (D. Smith, T. Yakutchik, personal communication). Concern over groundwater has led Peel Region to recently undertake an investigation of its groundwater resources (J. Savage personal communication). This investigation is currently ongoing.

Table 3.6 lists some hydraulic properties of the deep aquifers determined from pumping tests.

3.3 SURFACE WATER HYDROLOGY

3.3.1 Headwater Streams

The dynamics of groundwater contribution to headwater streams has been investigated over a two year period in the Duffins Creek Basin using detailed instrumentation and geochemistry (Roulet 1989a, b, Hill 1990a, b).

Table 3.5

Annual Groundwater Production for Municipal Wells at Newmarket, Aurora and Oak Ridges

Annual Groundwater Production (m^3x10^6)

Year	Newmarket	Aurora	Oak Ridges
1980	3.18	-	-
1981	3.23	-	-
1982	3.33	3.34	-
1983	3.55	3.64	-
1984	3.75	4.11	-
1985	3.93	4.37	-
1986	4.21	4.77	0.55
1987	4.70	-	0.76
1988	5.45	4.79	0.74
1989	5.84	5.01	0.79

Source: J. Sibbald, Superintendent Technical Support, Engineering Department, Regional Municipality of York.

Table 3.6

Hydraulic Properties of Deep Aquifers in the Oak Ridges Moraine Area

Aquifer	Well	Storativity	Transmissivity (m^2/day)	Reference
Newmarket	#16	-	460	International Water Supply (1983)
	TW 1/76	$5.4x10^{-4}$	418	International Water Supply (1976)
	No 1 Yonge St.	$2.67x10^{-6}$	500	International Water Supply (1976)
Aurora	#5	$4x10^{-3}$	670	International Water Supply (1988)
	#2, 3	-	1790	Hydrology Consultants (1977)

Small treed, spring swamps, which may make up only 2 percent of the headwater basin area are significant source areas for first and second order streams and convey groundwater via direct subsurface seepage or as overland flow from streamlets which discharge from isolated points located above the surface of the stream (Roulet 1989a). In Roulet's (1989a) study area, which covered 1.57 km^2 and contained two first order streams and a second order stream, groundwater discharge accounted for 94 percent of total basin discharge, and occurred as diffuse subsurface seepage and streamlet discharge. The water table was found to vary only slightly during the year, with the average change being only 0.01m, thereby providing a relatively stable wetland. Groundwater discharge to the stream was calculated as 0.035 L/s per metre length of stream or 3.024 $m^3/d/$ per metre length of stream on a daily basis.

Groundwater chemistry in the swamp area suggests that groundwater consists of two components, a younger component with relatively short residence time, contributed from a local flow system developed on the hill slope, and an older, more regional component, contributed from a deeper flow system within the Oak Ridges Aquifer Complex. This is consistent with observations by Funk (1977) in the Bowmanville, Soper, Wilmot Creek Basins to the east, who suggested that groundwater discharging from the break in topographic slope consisted of local and regional flow components.

Study of stormflow events showed that the basin was very responsive to rainfall events, but compared with other temperate swamps, the study swamp produced less stormflow suggesting greater subsurface storage capacity in the wetland (Roulet 1989b). This attenuation of stormflow is significant in reducing flooding downstream.

The wetlands which create the headwater streams exist because groundwater discharges in that location. Therefore any decrease in groundwater recharge or increased groundwater extraction may affect the maintenance and distribution of wetland/headwater stream areas. Headwater streams that originate in the Oak Ridges Moraine Area are illustrated in Plate 3 and are listed in Table 3.7. A number of the headwater creeks, however, are not named. Many of the headwater streams in the Oak Ridges Moraine Area support a coldwater fish habitat which

TABLE 3.7

Headwater Streams in the Oak Ridges Moraine Area

I. **Streams Flowing South to Lake Ontario**

Peel Region

Silver Creek	(Credit River)
Little Credit River	(Credit River)
Lindsay Creek	(West Branch Humber River)
Centreville Creek	(Humber River)
Humber River	
Cold Creek	(Humber River)

York Region

East Humber River	
Rouge River	
Bruce Creek	(Rouge River)
Little Rouge Creek	
West Duffin Creek	

Durham Region

Duffin Creek
Lynde Creek
Oshawa Creek
East Oshawa Creek
Bowmanville Creek
Soper Creek
Wilmot Creek

TABLE 3.7 (cont.)

II **Streams Flowing North to Lake Simcoe**

Peel Region

Schomberg River

York Region

Schomberg River
Holland River
Bogart Creek (East Holland River)
Black River
Mount Albert Creek (Black River)
Vivian Creek (Black River)

Durham Region

Pefferlaw Brook
Uxbridge Brook
Beaverton River

III **Streams Flowing North to Lake Scugog**

Durham Region

Nonquon River
Eastcross Creek

is threatened by increased urbanization (MNR 1988, 1989). The extent of the coldwater stream zone is outlined on Plate 3, and conforms closely to the geographic extent of the Oak Ridges Moraine Area.

IV LAND USE

4.1 EXISTING AND PROPOSED LAND USE - OFFICIAL PLANS

Official Plans for Durham Region and the Town of Caledon in Peel Region, and the draft Official Plan for York Region recognize specifically the significance of the Oak Ridges Moraine as a prominent landscape feature that is important as a source of groundwater and for maintaining baseflow to streams. The question, however, is the extent to which the Oak Ridges Moraine as a significant entity is actually recognized in the land use development process, since each Region also recognizes the importance of other land use activities including agriculture, aggregate extraction and housing.

4.2 LAND USE CONCERNS

4.2.1 Aggregate Extraction

Aggregate in the form of sand and gravel is usually extracted at the surface, commonly no deeper than 15-18m (McLellan 1975). Extraction activity causes permanent changes in natural land forms. In the past, aggregate extraction has been conducted in a haphazard and uncontrolled manner with very little thought to rehabilitation and post-extraction land use, and when left in a derelict state these pits become at the very least an eyesore and sometimes the site of illegal dumping of waste material.

The need to control aggregate extraction resulted in the Pits and Quarries Control Act of 1971 which was recently superseded by Bill 170 (1989) that "will clear up most of the definitional, administrative and enforcement difficulties of the predecessor. Emphasis is placed on better rehabilitation, more municipal liaison, municipal remuneration and power to suspend a license" (McLellan 1983).

In Peel Region establishment of new pits and quarries and expansion of existing pits and quarries by 20 ha or more requires an amendment to the Official Plan. Applications are assessed on, among other things, potential impact on Regional water supply systems and possible changes to ground and surface water systems. The Region also encourages the progressive rehabilitation of all pits and quarries towards a predetermined after-use (Regional Municipality of Peel 1988).

In York Region, aggregate resources will be protected from encroachment of incompatible uses through land use policies incorporated into Official Plans of area municipalities. New pits and quarries, or the expansion of existing facilities require amendments to Zoning By-Law and/or the Official Plan. The proponent must demonstrate that effects of aggregate extraction will be minimal on the natural environment including surface water and groundwater (Regional Municipality of York 1987).

In Durham Region, areas allocated for aggregate extraction are identified on the Official Plan for the Region. New pits and quarries or the expansion of existing facilities cannot extend beyond the boundaries of the Mineral Aggregate Resource Extraction Areas without an amendment to the Official Plan of the Region and the appropriate area municipal by-laws. Applicants must identify impacts on the physical environment as well as the possible effect on the water table or surface drainage pattern. More specific requirements are listed in the Official Plan of the Region (Regional Municipality of Durham 1989).

Major impacts, resulting from aggregate extraction include the physical destruction of land forms, the removal of vegetation and topsoil, the disturbance of natural drainage, the potential loss of farmland, and the impact of traffic, noise and dust on rural residents. In terms of impacts on groundwater and the natural function of the moraine area, the following situations may arise:

* Groundwater Interference - Excavation of a pit through a perched aquifer can cause excessive drainage and loss of the aquifer.

- Excavation of a pit below the regional water table can cause a lowering or drawdown of the water table, particularly if the pit is dewatered, and perhaps lower water levels in nearby private wells.

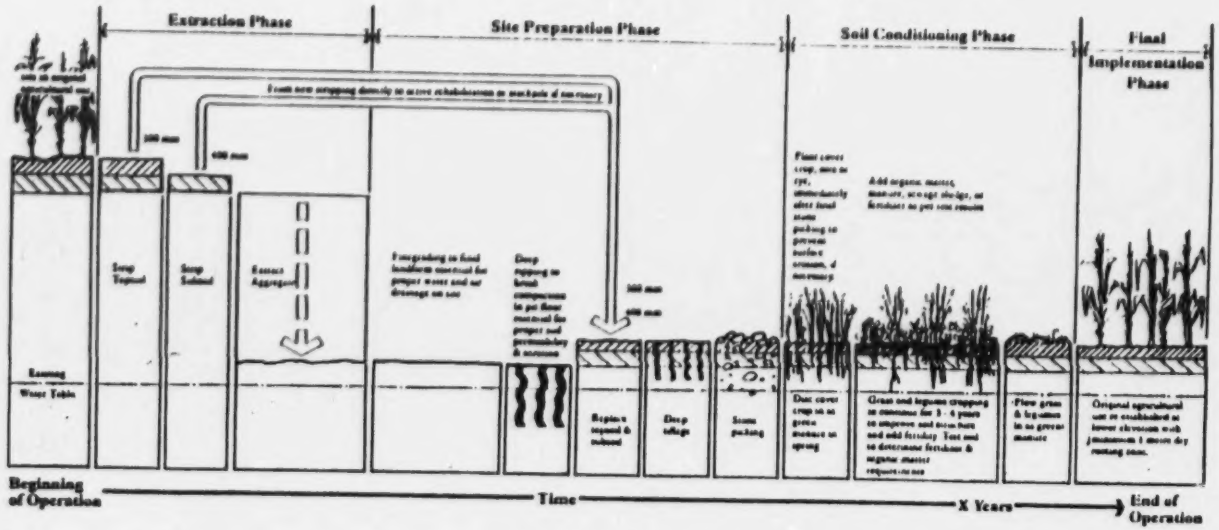
* Ground Compaction - The use of heavy equipment during normal pit operations can cause ground compaction and can reduce the permeability of the ground surface.

* Impacts of Siltation - Siltation ponds associated with washing operations can plug porosity of the ground surface and impede infiltration.
- Silty wash water discharged to streams can increase stream turbidity resulting in the destruction of fish habitat.

While pit operations can affect infiltration by compaction and siltation, rehabilitation of the pit through deep cultivation and recontouring can enhance the recharge characteristics of the pit by containing runoff on site. In the case where a pit is developed below the water table, and a permanent pond is produced, a net loss of water will occur from the site due to evaporation.

Where pit operations occur near or below the water table, impacts on groundwater quantity and quality should be a major consideration. Chemicals used during normal operations and fuel are possible contaminants if spilled or improperly used.

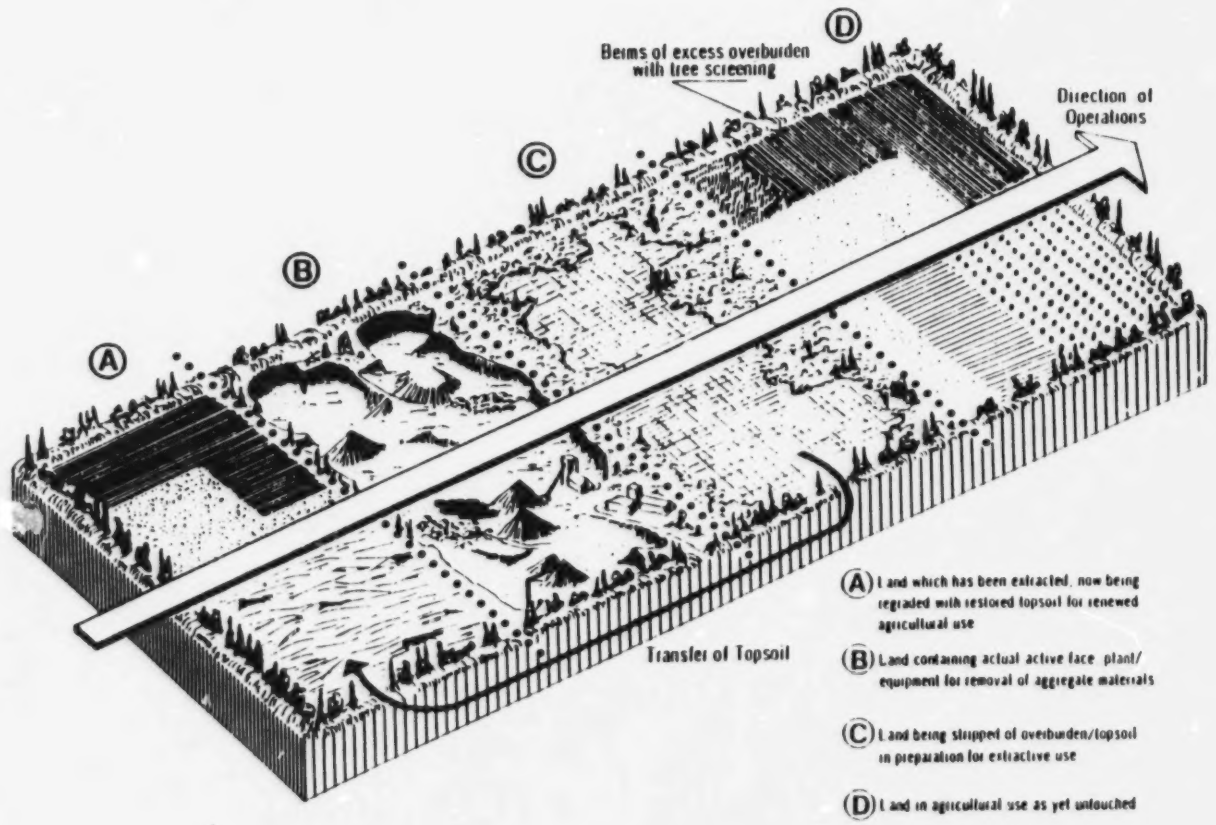
Properly planned aggregate extraction can result in rehabilitated land, which, through topsoil regrading and landscape redesign, is capable of supporting agriculture and producing recreational land for use as parks, forests and golf courses. Figure 4.1 shows a prospective rehabilitation sequence for land to be restored for agriculture. Figure 4.2 shows progressive rehabilitation at an operating site.



Reproduced from Mackintosh and Mozuratus, 1982. Mineral Resources Branch, Ontario Ministry of Natural Resources

Source: McLellan (1983)

INTERA Technologies	Progressive Rehabilitation Sequence for Restoration to an Agricultural After-Use	Figure 4.1


D
Berms of excess overburden with tree screening
Direction of Operations
C
B
A
Transfer of Topsoil
(A) Land which has been extracted, now being regraded with restored topsoil for renewed agricultural use
(B) Land containing actual active face plant/ equipment for removal of aggregate materials
(C) Land being stripped of overburden/topsoil in preparation for extractive use
(D) Land in agricultural use as yet untouched

Reproduced from McLellan and Graham, 1979 "Phased Rehabilitation System Guidelines" Interface

Source: McLellan (1983)

INTERA Technologies	Progressive Rehabilitation Model for Aggregate Pits	Figure 4.2

Aggregate resources as mapped and classified by the Ontario Geological Survey (1980a, b, c, d, 1981, 1984, 1986) are shown as deposits of primary and secondary significance on Plate 5.

4.2.2 Rural Estate Development

The scenic beauty of moraine topography coupled with the rather marginal agricultural capacity in large portions of the moraine, makes the moraine a suitable area for rural estate development.

In Peel Region, the Palgrave estate area has been approved for estate residential development (Colfield, personal communication). In York and Durham Regions, rural estate development requires an amendment to the Official Plan.

In all cases applications for approval must be accompanied by a site report confirming the capability of the site to provide adequate water and sewage disposal. Environmental reporting requirements in the Palgrave area, Town of Caledon, are especially stringent. Environmental investigations involving slope definition, soil and soil drainage classification, surface hydrology, vegetation and wildlife, stratigraphic logging and groundwater sampling are required prior to the commencement of the design of the subdivision (Town of Caledon).

The major concern with subdivision development in the moraine area is the impact of septic systems on well water quality, particularly with the production of nitrate, which may cause methemoglobinemia or "blue baby" condition in infants. The Ontario Drinking Water Guidelines for nitrate is set at a concentration of 10 mg/l nitrate as nitrogen (MOE 1983).

Other concerns with septic systems include the disposal of organic solvents and other organic compounds that are routinely disposed of in septic systems and can cause impairment to potable water supplies.

Rural villages and hamlets in the moraine area with small lots and shallow groundwater supplies are particularly susceptible to contamination from septic tank effluent and agricultural activity. Nitrate levels are seen to be increasing in groundwater supplies at Caledon East and Alton in Peel Region (B. Cooper, personal communication).

At Musselman Lake, 24 percent of the sampled wells contained nitrate levels in excess of provincial drinking water guidelines because septic systems were located too close to water supplies. Sixty-two percent of the sewage systems failed to meet current standards (MOE 1987). Guidelines for private sewage disposal systems are given in MOE (1982) and includes recommendations for site investigations.

The well drained characteristics of soils over much of the moraine area optimize sewage effluent infiltration, and potential groundwater quality impacts. Detailed investigation of a septic tile bed in an outwash sand aquifer near Cambridge, Ontario indicated that in hydrogeologic conditions similar to those found within the Oak Ridges Moraine Area, a plume of nitrate contaminated groundwater containing concentration of nitrates in excess of twice the provincial drinking water guidelines can extend more than 60 m beyond the septic tank (Robertson et al 1989).

One way to lessen the impact of septic tank effluent on groundwater quality is to increase lot size, thereby increasing the amount of dilution from natural recharge. However this scenario increases the price of homes because of increased land costs. Other alternatives include:

* alternative sewage treatment systems and,
* communal sewage treatment systems

Present septic tank and tile field design may be inadequate for certain housing densities. Alternative sewage treatment designs may be appropriate for certain conditions but practical demonstrations into their utility under Ontario conditions has not been undertaken. Alternative systems include: (i) red mud filters which utilize clinoptilite and zeolite mixed with sand to

promote ion exchange, (ii) circulating sand filters which circulate septic effluent through an aerobic sand filter and (iii) peat beds. (B. Cooper, personal communication) Peat beds, which utilize tile beds backfilled with peat have been successfully operated for more than ten years in Maine.

Another alternative is to construct communal sewage treatment facilities for subdivisions or groups of subdivisions. This alternative would require larger scale systems and would require regular maintenance to prevent system failure. As well, these systems would be regulated under the Environmental Protection Act, and MOE's Reasonable Use Guidelines which specify maximum contaminant concentrations at the subdivision boundary would apply.

4.2.3 Golf Courses

The Oak Ridges Moraine Area is ideally suited for the development of golf courses because of its proximity to Metropolitan Toronto and the rolling topography provides a scenically interesting and technically challenging layout. As well, golf courses are alternative land uses following aggregate extraction.

Some concern has been expressed with the irrigation demands of proposed golf courses competing with municipal supplies from the deeper aquifers in York Region (Yakutchik, Smith personal communication).

Other concerns relate to the impact of fertilizer and pesticide application to golf courses on nitrate and pesticide concentrations in shallow groundwater supplies. There has been no groundwater monitoring of the impacts of golf courses on the Oak Ridges Moraine (Mellary, personal communication). Elsewhere estimates of nitrogen leaching from fertilizer range from 30-60 percent and has resulted in predicted nitrate-nitrogen concentrations in groundwater on the order of 5-8 mg/l for a golf course located in a gravel outwash plain in Massachusetts (Horsley and Morca 1990).

Pesticide usage on golf courses includes fungicides, insecticides and herbicides. Previous pesticide studies by MOE on agricultural use of pesticides indicate that sandy soils with very shallow groundwater conditions are susceptible to contamination from soluble pesticides (MOE 1986, 1987, 1989) but there is a lack of monitoring data for determining impacts from golf course application of pesticides.

4.2.4 Road Salt Application

Increases in urban development result in the increased use of road salt in arterial roadways and subdivision roads. Road salt contamination complaints account for the greatest percentage of water quality complaints in MOE Central Region (R. Hodgins, personal communication).

Shallow groundwater supplies adjacent to major arterial roadways are particularly susceptible to road salt contamination. In Ballantrae, a small community in the Oak Ridges Moraine, in the Town of Whitchurch-Stouffville, 44 of 46 wells finished in the upper aquifer were found to have elevated concentrations of chloride, sodium, nitrate-nitrogen and bacteria to the extent that groundwater supplies were deemed unpotable. The elevated chloride and sodium levels were attributed to the application of road salt (MOE 1977, UMA Engineering Ltd. 1985). Provincial guidelines for chloride levels in drinking water are set at 250 mg/l which is based on aesthetic (i.e. taste) rather than human health criteria (MOE 1983). Sodium levels are not set under the provincial guidelines; however, when levels exceed 20 mg/l, the local medical officer of health is notified so that the information can be disseminated to local physicians for patients on sodium restricted diets.

4.2.5 Waste Disposal Sites

Numerous waste disposal sites are scattered throughout the Oak Ridges Moraine Area, (Hodgins, personal communication) and their locations are shown on Plate 4. Waste disposal sites contain predominantly municipal garbage, however some sites exist where the disposal history is not well known and these sites may have received industrial waste in the past.

Waste disposal sites may impact on groundwater and surface water quality. Under present legislation waste disposal sites require a certificate of approval from the MOE to operate and are subject to a technical study on the potential impact to the environment.

The largest landfill site in the moraine area is located at Maple, in a former sand and gravel pit. The summary of a case study of the Keele Valley site indicate:

* landfills still arouse public controversy
* negotiations for securing provision to operate sanitary landfills can be lengthy
* extensive environmental protection controls can be instituted to minimize possible adverse effects of sanitary landfills

(McKechnie et al 1983)

The Stouffville landfill site which exists in the Oak Ridges Moraine in Highway 48 just south of Musselman Lake shows the development of a chloride plume within the Oak Ridges Aquifer. Public concern was raised because of the past practice of dumping liquid industrial waste into rapidly draining kettle depressions on the site (Proulx and Farvolden 1989). Dissolved organic carbon and volatile organic compounds were reported at low concentrations in several downgradient wells (Proulx and Farvolden 1989).

4.2.6 Agriculture

The droughty soils and steep hillslopes over much of the moraine area restrict the amount and type of agricultural activity that can be undertaken. On gentle hillslopes, depending on soil texture, land can be pastured for horse and beef cattle operations. Some amount of cropping including hay, corn, soybeans and wheat are carried out throughout the moraine area. Due to the low soil fertility, however, the land must be ammended with additions of manure or chemical fertilizers and crop rotation. Irrigation is not carried out to any great extent within the moraine area.

The Township of Uxbridge lies entirely within the moraine area, and in 1981, 57 percent of the total land area was occupied by farms, and 58 percent of the total farm area was cropped, the remainder being woodland and pasture (Chapman and Putnam 1984). Discussions with agricultural representatives from Ontario Ministry of Agriculture and Food did not indicate any concerns with impacts of agricultural chemicals or manure on groundwater quality. However, agricultural practices are thought to be the cause of elevated levels of nitrate in groundwater in the Palgrave and Mono Mills areas of Peel Region (M. Ponti, R. Stanley, personal communication).

INTERN KENTING

V CONCLUSIONS

Conclusions are presented in a format that addresses the key elements of the study listed in Section 1.1 and referred to in the Terms of Reference (Appendix B).

1) Considerable information is available on general hydrologic and geologic conditions within the Oak Ridges Moraine, however, more detailed field investigations are required to answer more completely key elements (2), (4) and (6).

2) The Oak Ridges Moraine Area contains aquifer complexes in the upper portion of the moraine which are an important source of groundwater for domestic and stock use and municipal supplies in Stouffville and Uxbridge. Deeper aquifers are located within a broad bedrock valley system which extends beneath the western half of the moraine area, and provides municipal water supplies for Oak Ridges, Aurora and Newmarket. Slow leakage of water from the upper aquifer complex is an important source of recharge to the deeper aquifers.

3) Watercourses originating within the moraine area flow in one of three general directions: south toward Lake Ontario; north toward Lake Simcoe; and northeast toward Lake Scugog.

4) Groundwater discharge on the flanks of the moraine provides a source area for headwater streams via small spring swamps. The low temperature of the discharging groundwater provides a habitat for important coldwater fish species such as brook trout and brown trout.

Recharge is variable throughout the moraine area. North of the northerly extent of the Halton Till, in the west-central portion of the moraine, the moraine aquifer complex is unconfined which facilitates rapid recharge. Where the moraine area is overlain by the Halton Till, "windows" of relatively high permeability exist, which allow recharge to the moraine aquifer complex. In other areas recharge is impeded by fine grained materials in the till. Areas of relatively rapid recharge through the Halton Till can be identified by depressions in the water table.

Baseflow calculations for several watersheds originating within the moraine area indicated that baseflow as a percentage of streamflow is variable within the same watershed as well as between watersheds. For example, baseflow accounted for 94 percent of streamflow first and second order streams in the headwaters of Duffins Creek, but for only 50 percent of streamflow in the lower reaches. In West Duffins Creek, baseflow in the mid-reaches of the basin accounted for 37 percent of streamflow compared to 61 percent in the lower reaches.

Baseflow in the mid- and lower-reaches of the Rouge River accounted for 27 - 30 percent of streamflow compared to 37 - 61 percent for West Duffins Creek.

5) The implications of uncontrolled land use changes brought about by increased development within the moraine area include:

* Destruction of natural landforms through the extraction of aggregate materials.

* Impairment of groundwater and surface water quality from the following activities:
  - impacts of septic system and landfill wastes on groundwater supplies
  - application of de-icing salt to highways and subdivision roads
  - chemical spills during aggregate extraction
  - intensive farming of cash crops such as corn and soybeans which require inputs of chemical fertilizers and pesticides

* Interference of groundwater quantity from the following activities:
  - excavation of aggregate pit operations below the water table
  - private and municipal water supplies, industrial processes and irrigation of golf courses

6) The identification of specific areas of significant recharge for the purposes of applying development controls requires a comprehensive evaluation of the entire Oak Ridges Moraine Area, and is beyond the scope of this study.

Significant areas of groundwater discharge include the wetland areas feeding headwater streams and the major flowing artisian well zone west of Stouffville.

7) Aggregate extraction, when properly assessed for its environmental impact, does not appear to impact negatively on groundwater provided that post extractive rehabilitation can maintain the recharge function of the land. Aggregate extraction does, however, permanently change the physical appearance of the landform.

8) Alternative sewage treatment disposal including communal systems may be appropriate for future residential and commercial development in the moraine area.

9) Currently, there is no consistency as to environmental data requirements during change in land use throughout the moraine area; nor is there any long term requirements for monitoring to provide baseline control and to evaluate environmental impacts on groundwater.

VI RECOMMENDATIONS

Protection of the moraine area will be determined by how well the Regional and local councils interpret and implement their own Official Plans. Recognizing that conflicting land use priorities may arise that may impact on the Oak Ridges Moraine, the following recommendations are given:

1) An analysis of shallow water table conditions and areas of induced recharge in aquifers within the Oak Ridges Moraine Area should be undertaken since these areas are important recharge areas, and are most susceptible to contamination from land applied chemicals, surface spills or leaking underground tanks and septic systems. Consideration should be given to maintaining this land in a natural state, through the encouragement of land stewardship programs.

Major transportation corridors should avoid as much as possible routing along unconfined sections of the moraine to minimize impacts of road salting and accidental spills of transported hazardous materials.

Commercial operations which may store hazardous liquids on site and landfills should be discouraged from developing on unconfined portions of the moraine.

2) Municipalities should consider the concept of wellhead protection, which identifies and protects recharge areas of important sources of groundwater such as municipal drinking water supplies.

3) The increased runoff that will occur through development and urbanization should be redirected back into the ground through the use of storm retention ponds roadside ditches, and other infiltration techniques so that recharge to groundwater is not depleted.

4) The significance of the small wetland areas as a source area for coldwater streams originating within the Oak Ridges Moraine Area should be recognized. These wetland areas should be mapped, and their preservation should be a criterion for approving future development applications.

5) The evaluation of the impacts of land use changes on the hydrological processes within the moraine area require detailed studies. These studies should be made a requirement of the proponent, as part of the application for any development that may impact environmental quality. While these types of studies are mentioned in the Regional Plans, the actual reporting requirements are vague. The evaluation and reporting requirements for the Town of Caledon Rural Estate Residential Policy Area should be recognized as having considerable merit and should be pursued as a model of a common sense approach to environmental assessments by other municipalities. This detail of environmental assessment should be extended beyond rural estate development to include all development which may impact present environmental conditions.

6) Alternatives to current designs for sewage treatment should be evaluated through the use of field scale studies. These alternatives should include innovative system designs and communal systems. Funding for such studies could be provided by MOE's Research and Technology Branch.

7) As well as the requirement for detailed environmental assessment, provisions should be made at the planning stages of a proposed development within the moraine area for the proponent to monitor groundwater and surface water. Monitoring of water levels and water quality should be maintained by the proponent to establish baseline conditions so that future impacts of the development can be evaluated. This monitoring should be undertaken following strict sampling and analytical protocols. Results should be sent to the Regional Municipality.

8) The Regional Municipalities should establish a data base to accept environmental monitoring data including: borehole stratigraphic information, soil and water quality data, water level information, water takings, potential sources of contamination, etc. Data should be obtained using established protocols and coordinated with the Regions so that a standardized data base is obtained. This data should be used in future planning decisions.

9) Regional Municipalities within the GTA should sponsor on a regular basis (say every three years) a conference to review the environmental status of significant areas such as the Oak Ridges Moraine Area. The conference should be attended by engineers, planners, health authorities, conservation authorities, Provincial ministries and special interest groups to promote an understanding of the problems encountered by various jurisdictions, and to evaluate the impact of progressive development.

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APPENDIX A

LIST OF INDIVIDUALS CONTACTED DURING THE STUDY

APPENDIX A

List of Individuals Contacted During The Study

Name	Affiliation
Cam Baker	Supervisor Quaternary Geology, Ontario Geological Survey, Ontario Ministry of Northern Development and Mines
James Barker	Professor, Department Earth Sciences, University of Waterloo
Peter Barnett	Geologist Quaternary Geology, Ontario Geological Survey, Ontario Ministry of Northern Development and Mines
Jon Bissett	Fisheries Habitat Rehabilitation Biologist, Fish and Wildlife Section, Ontario Ministry of Natural Resources (Maple)
William Broadworth	Farm Business Advisor, Ontario Ministry of Agriculture and Food, Durham West County Office
Rick Colfield	Geologist/Planner, Planning Policy Section, Regional Municipality of Peel
Brian Cooper	Project Engineering Officer, Municipal Approvals, Approvals Branch, Ontario Ministry of the Environment
Jim D'Cruz	Hydrogeologist, Ontario Ministry of the Environment, Central Region
David Dyce	Manager of Resource Management Section, Metropolitan Toronto and Region Conservation Authority
Nick Eyles	Professor, Department Geology, University of Toronto
Robert Gorman	Geologist, Aggregate Assessment Office, Ontario Ministry of Northern Development and Mines
Alan Hill	Professor, Department Geography, York University
Brian Hindley	Project Manager for Watershed Studies, Metropolitan Toronto and Region Conservation Authority
Ross Hodgins	Ontario Ministry of the Environment, Central Region

Ken Howard	Professor, Department Geology, University of Toronto
Richard Hubbard	Waste Quality Specialist, Metropolitan Toronto and Region Conservation Authority
John Huby	Municipal Services Design Engineer, Regional Municipality of York
Paul Karrow	Professor, Department Earth Sciences, University of Waterloo
Alexander (Sandy) McLellan	Professor, Department Geography, University of Waterloo
Andy Mellary	Coordinator, Environmental Studies, Ontario Ministry of the Environment, Central Region
Amer Mukherjee	District Geologist, Ontario Ministry of Natural Resources (Maple)
Mark Ponti	Planner, Town of Caledon
Mike Pudister	Senior Resource Planner, Credit Valley Conservation Authority
Barry Rose	Farm Business Advisor, Ontario Ministry of Agriculture and Food, York County Office
Nigel Roulet	Professor, Department Geography, York University
John Savage	Director of Engineering and Construction, Regional Municipality of Peel
John Sibbald	Superintendent Technical Support, Engineering Department, Regional Muncipality of York
Barry Sinclair	Acting Agricultural Rep., Ontario Ministry of Agriculture and Food, Peel County Office
Derek Smith	Ontario Ministry of the Environment, Central Region
Ralph Stanley	Senior Public Health Inspector, Regional Municipality of Peel
Barry West	Engineer, Regional Municipality of York, Public Health Branch
John Westgate	Professor, Department Geology, University of Toronto
Tony Yakutchik	Consulting Hydrogeologist; formerly: Supervisor Ground Water Management, Water Resources Branch, Ontario Ministry of the Environment

APPENDIX B

TERMS OF REFERENCE

January 2, 1990

TERMS OF REFERENCE

SIGNIFICANCE OF THE OAK RIDGES MORAINE AREA

GREATER TORONTO GREENLANDS STRATEGY

BACKGROUND

On October 17, 1989, Premier David Peterson appointed Ron Kanter, MPP for St. Andrews-St. Patrick to develop a Greater Toronto Greenlands Strategy.

The area of study, commonly referred to as the Greater Toronto Area (GTA), includes the Regional Municipalities of Halton, Peel, York and Durham and the Municipality of Metropolitan Toronto.

The strategy is to make recommendations in three key areas pertaining to:

- identification of a regional greenspace system
- development of various control mechanisms to protect greenlands and measures to enhance them, and
- institutional arrangements to most effectively assist in the implementation of the strategy.

More detailed Terms of Reference on the Greater Toronto Greenlands Strategy are attached.

To assist in developing a strategy, several studies will be undertaken to address specific aspects of the three tasks identified. One such study is assessing the significance of the Oak Ridges Moraine Area.

The development of the strategy is on an extremely tight time line, due to be completed by June, 1990. As a result, little time will be available for original research or data collection. Maximum use will be made of existing information/data and examples or case studies from elsewhere.

/2

The term "greenlands" will include:

- greenspace corridors and related outdoor recreation (e.g. hiking, biking, walking, cross country skiing trails),
- significant natural, cultural and archaeological areas, and
- natural processes/functions performed by greenlands (e.g. recharge/discharge).

In exploring a regional greenlands system for the GTA, the overall strategy will specifically examine:

- the river valleys
- the Niagara Escarpment
- the Oak Ridges Moraine
- the Lake Simcoe shoreline

Certain significant greenlands will be found outside of the river valleys, Niagara Escarpment, Oak Ridges Moraine and Lake Simcoe shoreline per se. Such areas will also be included in the study. Collectively, they can be considered to form a system or network of significant areas within the GTA.

While the strategy will be applicable to the Greater Toronto Area, it will <u>not</u> address the Lake Ontario waterfront. The future of the waterfront is currently the subject of a Royal Commission headed by David Crombie. It is expected however, that the Kanter Greenlands Strategy and the Crombie Waterfront initiative remain fully cognizant of the ongoings of the other and to the extent applicable, to interact and cooperate.

It must be noted that the focus of the overall strategy is on "regional" systems. It is not the intent to downplay "local" significance but limitations, particularly time, dictate a regional perspective.

/3

PURPOSE

The purpose of this particular study is to assess the significance of the Oak Ridges Moraine as a natural feature and to assess the significance of the Moraine Area as a recharge/discharge and headwater area for watercourses draining south to Lake Ontario and north to Lake Simcoe.

It is recognized that several different interpretations exist concerning the delineation of the Oak Ridges Moraine Area. The interpretation to be used for purposes of this study will be provided by the client.

KEY ELEMENTS OF THE STUDY

(1) Review existing information/data on the physiography, soils, geology and natural functions (e.g. recharge/discharge) of the Moraine Area. Review other information/data pertinent to the study, as deemed appropriate.

(2) In general, assess the significance of the Oak Ridges Moraine as a natural feature in relation to its hydrologic function

Provide a description, maps, etc. outlining the movement of ground water within and out of the Moraine Area.

(3) Identify those watercourses within the GTA, flowing north and south, that are considered to originate within the Moraine Area.

(4) Specifically, assess the significance of the Moraine Area as a headwater/source area and recharge/discharge area. If possible, quantify (approximate percentage) of base flow per watercourse originating in the Moraine Area.

(5) To the extent possible, identify the implications of uncontrolled land use changes within the Moraine Area from a natural processes perspective.

Assuming that more urban land use changes will occur in the Moraine Area, identify types of land uses and other development controls that should be considered to allow the Moraine to continue its natural function of water supply and related water quality.

/4

(6) To the extent known, identify specific areas of significance recharge/discharge that should be centred out for special development controls.

(7) Assess the implications of aggregate extraction on ground water and the ability of the Moraine Area to perform its natural functions as a source area.

(8) Document all pertinent data in report form.

(9) In carrying out the study, liaise with provincial ministries, conservation authorities, municipal officials, other agencies and groups, academics and individuals, as appropriate.

The client is to receive prior notice of any meetings/discussions anticipated with special interest groups.

TIMING

Time is of the essence. The study will be completed by February 28, 1990.

ADMINISTRATION

(1) Two formal progress meetings will be held:

- after the completion of task (4)
- upon completion of the draft report.

(2) Invoices are to be submitted at the completion of task (4) and after the final report has been accepted by the client.

(3) Four copies of the draft report are to be submitted for review by February 14, 1990.

(4) Ten copies of the final report and one unbound copy of the final report, suitable for reproduction, are to be submitted by February 28, 1990.

All reference material will be given to the client at the end of the study.

TERMS OF REFERENCE

ON THE

GREATER TORONTO GREENLANDS STRATEGY

Green landscapes and waterways adjacent to urban areas contribute greatly to the quality of life of Ontarians. They serve as significant recreational assets, particularly when linked together. They protect water quality in river courses and contribute to public safety by moderating flood levels. They also safeguard many facets of our cultural and natural heritage.

Recognizing these values, Mr. Kanter, M.P.P. St. Andrew-St. Patrick, will make recommendations pertaining to:

1. Identification of a regional system of natural areas and landscapes which will:

   - protect the diversity of fauna and flora, ecosystems, communities, and landforms of the GTA;
   - maintain the water quality and natural flow regulation of rivers and streams within the GTA;
   - provide expanded opportunities for a variety of public outdoor recreation activities near urban settings;
   - contribute to a continuous natural open space system to provide visual separation of communities and to provide continuous corridors between ecosystems;
   - protect significant scenic and cultural landscapes, including archaeological resources.

2. Development and coordination of appropriate protective and enhancement strategies for significant landscapes, including the examination of the role of municipal land use planning, private land stewardship, conservation easements, landowner agreements, provincial programs and incentives and public acquisition.

/2

3. Structuring of the most effective institutional arrangements to implement the strategy including consideration of new mechanisms such as Nature Trusts and other creative forms of community based conservation movements to compliment public sector initiatives. Initiatives to encourage private sector participation will also be encouraged.

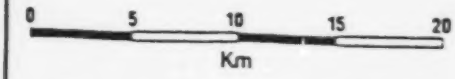
While most of the work of the greenlands strategy will focus on the valleys and waterways of the GTA, Mr. Kanter will also pay special attention to their relationship to the Lake Ontario waterfront, and to the ongoing activities of the Royal Commission on the Future of the Toronto Waterfront.

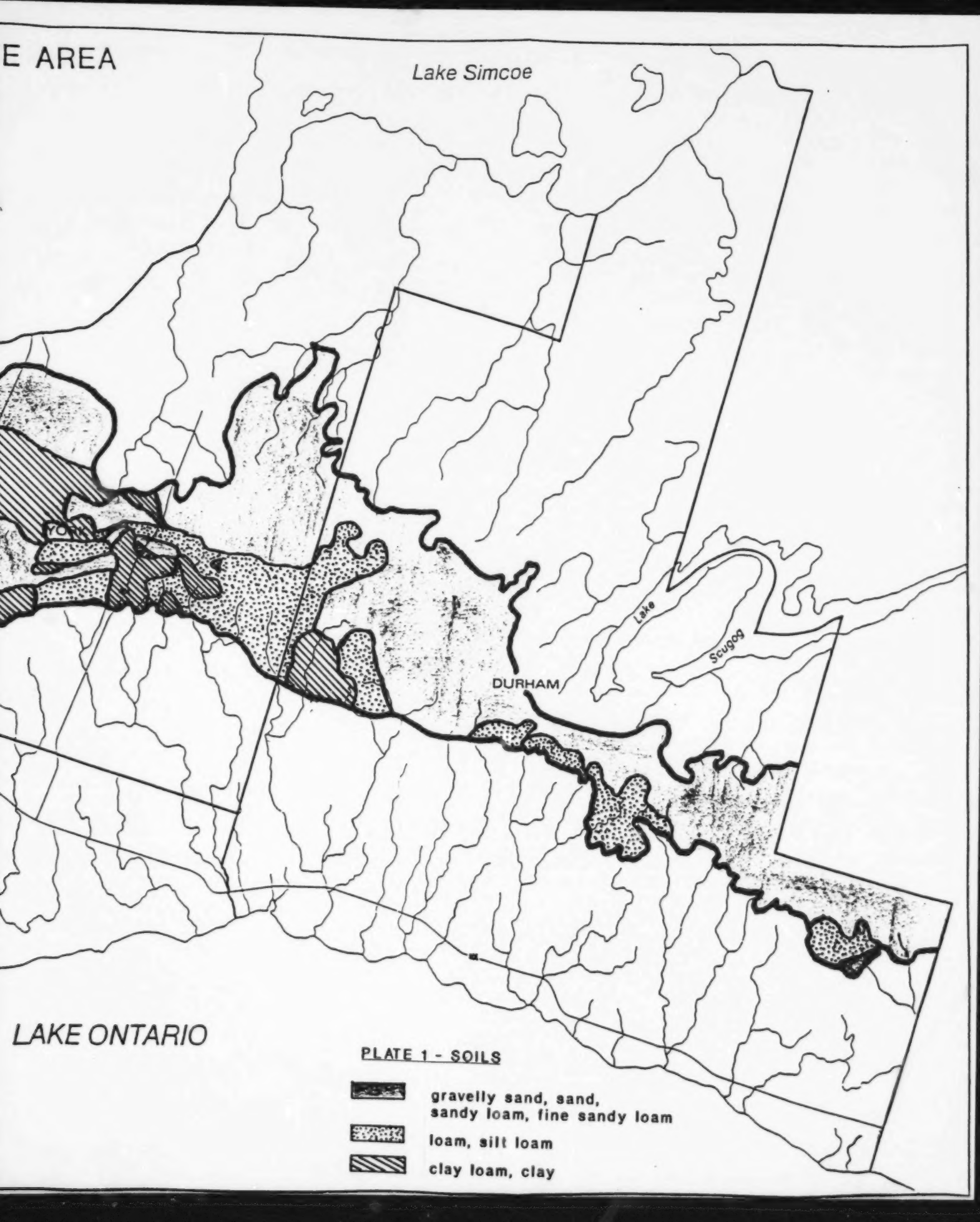
Mr. Kanter will call on the advice of experts, groups, agencies and governments experienced in the protection of natural landscapes to assist in his review.

The Greater Toronto Greenlands strategy will be provided to the Cabinet Committee on Housing and Community Development by June 1990.

Greater Toronto Area

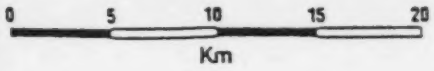
OAK RIDGES MORAINE




E AREA
Lake Simcoe
YORK
DURHAM
Lake
Scugog
LAKE ONTARIO
PLATE 1 - SOILS
gravelly sand, sand,
sandy loam, fine sandy loam
loam, silt loam
clay loam, clay

Greater Toronto Area

OAK RIDGES MORAINE AR



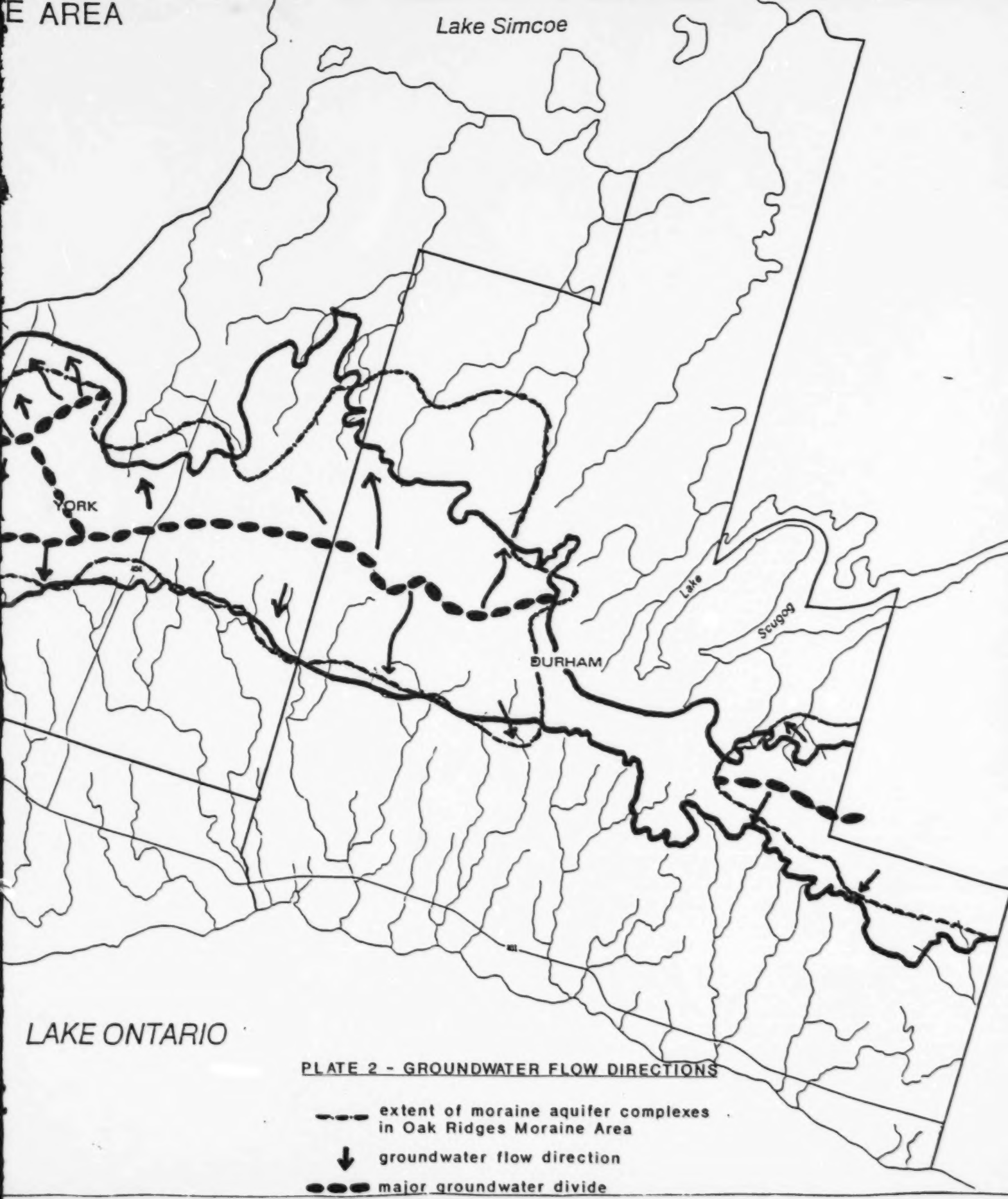


PLATE 2 - GROUNDWATER FLOW DIRECTIONS

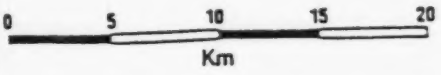
extent of moraine aquifer complexes in Oak Ridges Moraine Area

groundwater flow direction

major groundwater divide

Greater Toronto Area

OAK RIDGES MORAINE AR



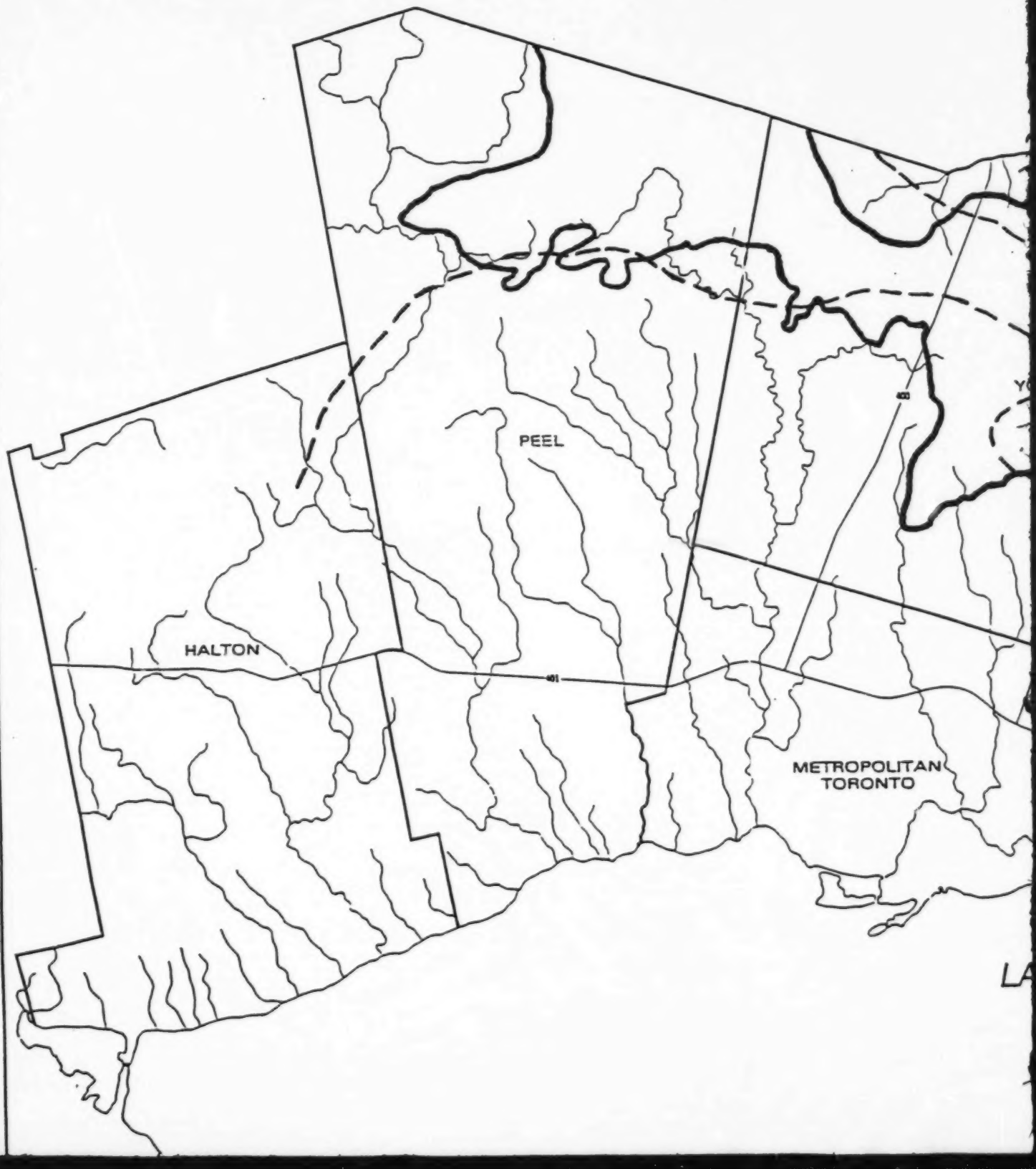
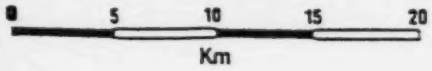


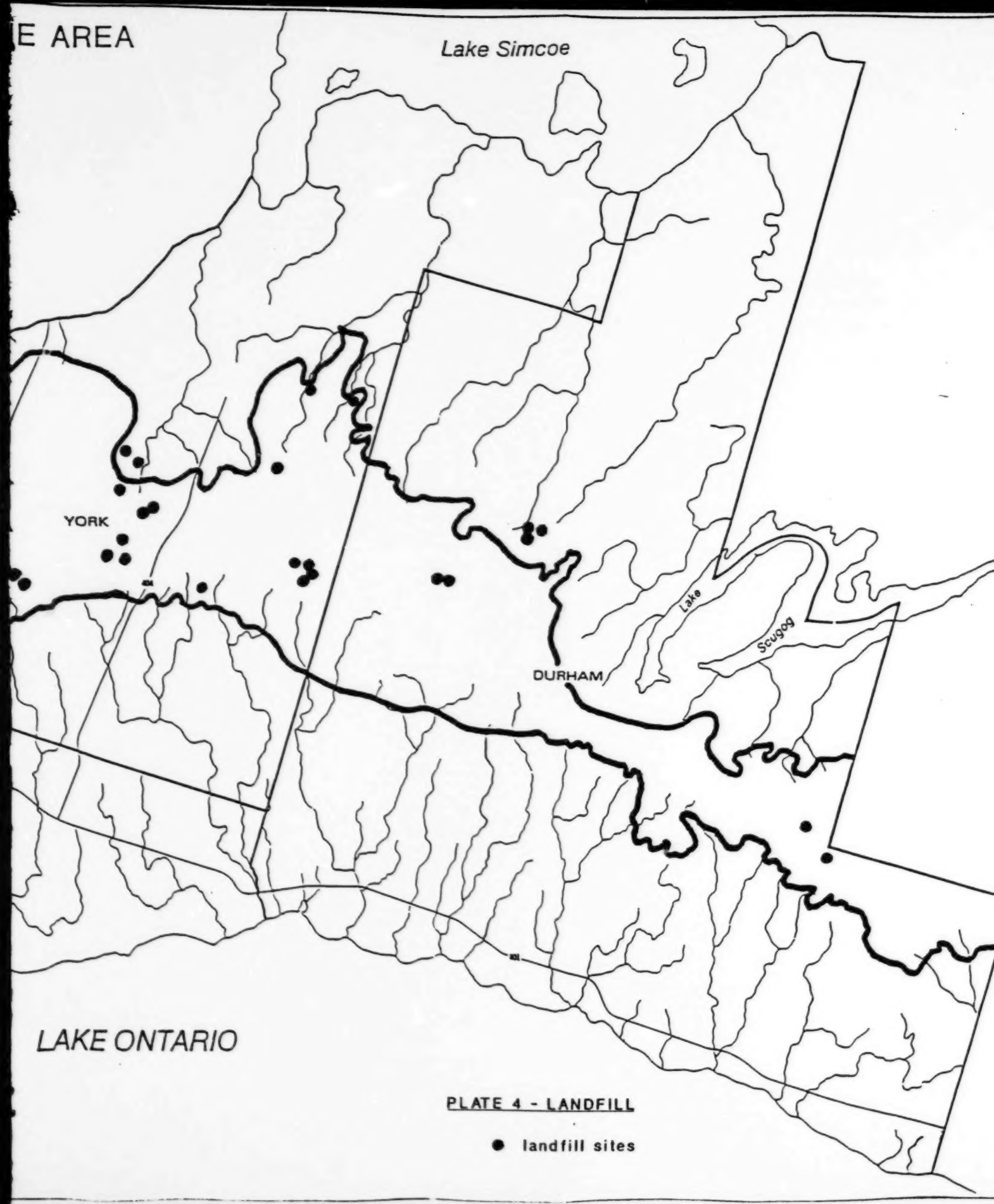
PLATE 3 - HEADWATER STREAMS

— — — coldwater stream zone

Greater Toronto Area

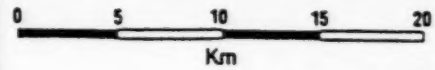
OAK RIDGES MORAINE AREA

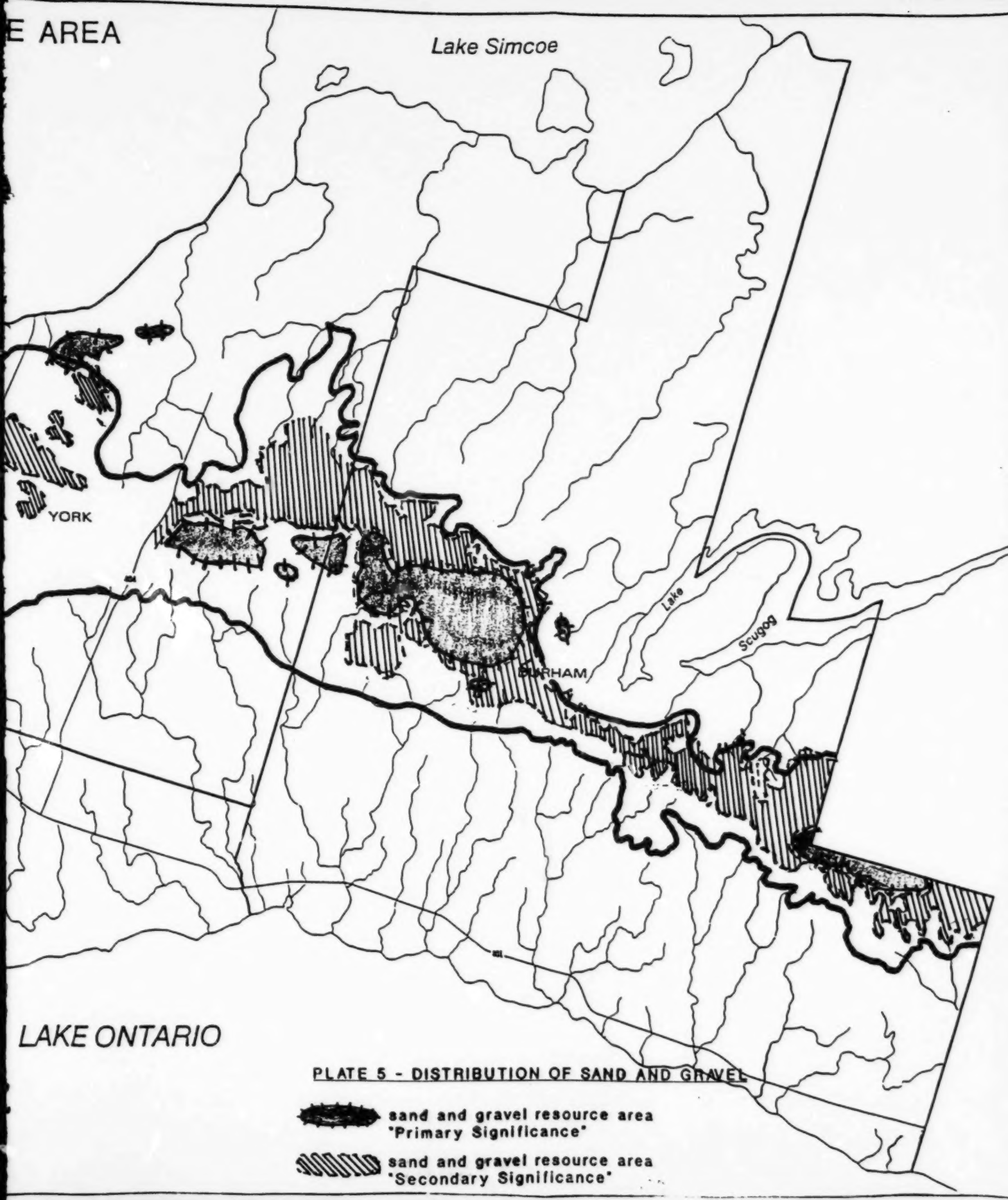



E AREA
Lake Simcoe
YORK
DURHAM
Lake
Scugog
LAKE ONTARIO
PLATE 4 - LANDFILL
landfill sites

Greater Toronto Area

OAK RIDGES MORAINE AREA




E AREA
Lake Simcoe
YORK
DURHAM
Lake
Scugog
LAKE ONTARIO
PLATE 5 - DISTRIBUTION OF SAND AND GRAVEL
sand and gravel resource area
'Primary Significance'
sand and gravel resource area
'Secondary Significance'